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BIONOMICS AND CONTROL
OF SOME
NORTHERN SPECIES OF TABANIDAE

LLOYD ALLAN MILLER

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The undersigned hereby certify that they have read and recommend to the School of Graduate Studies for acceptance, a thesis entitled **ECONOMICS AND CONTROL OF SOME NORTHERN SPECIES OF TABANIDAE**, submitted by **Lloyd Allan Miller, B.Sc.**, in partial fulfilment of the requirements for the degree of Master of Science.

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Date...April, 1950.

THE UNIVERSITY OF ALBERTA

BIONOMICS AND CONTROL OF SOME NORTHERN SPECIES OF TABANIDAE

A DISSERTATION

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

FACULTY ARTS AND SCIENCE

by

LLOYD ALLAN MILLER

EDMONTON, ALBERTA.

APRIL, 1950.

PREFACE

The members of the family Tabanidae (horseflies and deerflies) combine with the Culicidae (mosquitoes) and Simuliidae (blackflies) to form a formidable trio of blood-sucking flies in northern latitudes. Whilst of lesser importance than either the mosquitoes and blackflies, the tabanids, by virtue of their actual biting and annoying persistence, are of sufficient importance to warrant serious attention.

Studies reported on in this paper were carried out during the spring and summer months of 1948 and 1949 by the author while employed as a Technical Officer on the staff of the Household and Medical Entomology Unit, Division of Entomology, Science Service, Department of Agriculture, Canada. The project was part of a program of biological and control studies carried out by the Division of Entomology on behalf of the Canadian Defense Research Board and with the co-operation of that organization and other agencies.

The author wishes to express his appreciation to Professor B. Hocking of the University of Alberta who gave advice and guidance in the preparation of this thesis; to Dr. C. R. Twinn, Chief, Household and Medical Entomology Unit, of the Division of Entomology, at whose direction the project was carried out and who permitted the use of the data gathered while in the employ of his Unit; to the officers and personnel of the Defense Research Board Northern

Laboratory at Churchill, Manitoba, for numerous privileges and much assistance, without which the project could not have been completed; to Mr. H. James of the Dominion Parasite Laboratory, Belleville, for many helpful suggestions; to Professor E. H. Strickland, University of Alberta, who never has been hesitant in offering assistance; to Mr. G. E. Shewell and Dr. O. Peck, Division of Entomology, Dr. J. S. Rogers, University of Michigan, Dr. C. P. Alexander, Massachusetts Agricultural College, Amherst, Dr. E. Hughes, University of Oklahoma, Dr. R. B. Miller, Dr. E. Moss and Miss L. Kennedy, University of Alberta, for identifying material and /or offering information in their respective fields.

Finally the author wishes to record his appreciation of the services of three very able assistants, namely Messrs. C.B. Wall and B. C. Smith of the Defense Research Board, and Mr. J. Shemanchuck, Division of Entomology. The successful completion of the project is due, in large part, to the uncomplaining efforts of these three gentlemen.

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* * * * *

ABSTRACT

10 species of Hybomitra, 5 of Chrysops, and 1 of Atylotus are listed. Of these, Hybomitra itasca Philip, Hybomitra sp. (new?), and Atylotus ohioensis Hine are new records for the Churchill area. It has been established that the northern Tabanidae overwinter in the larval stage and most species have at least a 2-year life cycle. Problems in taxonomy are discussed briefly. Methods of rearing immature stages, collecting adults emerging in the field, estimating larval and adult populations, and correlating adult activity and weather conditions, are described. The presence of Prionocera dimidiata Lw., the larva of which is an important predator of Chrysops spp. larvae, is established. The chalcid, Diglochis occidentalis Ashm., was reared from the pupae of Hybomitra and Chrysops spp.. Dosages of 2,500, 10,000, and 160,000 ppm/mins. DDT and 2,500 ppm/mins. parathion are ineffective against larvae. 2,500 ppm/mins. DDT against pupae shows promise. 64 line drawings and photographs and 1 map illustrate the text, and data are presented in 10 tables and 8 graphs. The paper concludes with 38 references.

* * * * *

Literature Review

The Tabanidae, being of considerable economic importance, have no dearth of literature relating to them. The following review, however, is aimed primarily at recording the methods of other authors in control measures since it is hoped that these pests can eventually be controlled either by biological, chemical, or mechanical means.

Population and abundance studies, rearing techniques, habits and behavior, and problems in taxonomy have also been reviewed.

1. CONTROL

1.1. BIOLOGICAL

Eggs - Cameron (5) in Saskatchewan reported the presence of the proctotrypid Phanurus emersoni Gerault, in the egg masses of Chrysops moerens Walk. and C. mitis O.S.. This parasite has also been reported by Webb and Wells (34) in Nevada and Hatton (10) in British Columbia. Also present amongst the eggs of P. emersoni observed by Cameron were eggs of the small chalcid Trichogramma minutum Riley. Bailey (3) in Massachusetts reared the proctotrypid Telenomus goniopis Ash. from eggs of Tabanus atratus subsp. nantuckensis Hine.

Larvae - Jones and Bradley (14) in Louisiana have found the parasitic larvae of Phasiops flava Coq. (Dexiidae) in the larvae of Tabanus trimaculatus Pal. Beauv.

Pupae - Cameron (5) found the parasitic species Diglochis occidentalis Ash. (Pteromalidae: Chalcidoidea) in the pupae of C. moerens, C. mitis, and C. excitans Walk. and Trichopria tabanivora n.sp. (Diapriidae) from the pupae of C. mitis and T. reinwardtii Wied.

Jones and Bradley (14) reported that the pupa of the bombyliid, Anthrax lateralis Say freed itself from the pupa of T. annulatus Say and an adult later emerged.

Adults - The wasp, Bembex primaestate Johnson and Bower, was reported by Webb and Wells (34) to be predatory on the adults of T. insuetus O.S. and T. phaenops O.S.. The dead adults of these two species were found in the tunnels of the predator.

1.2. CHEMICAL

Larvae - Gjullin (8), tested one part of DDT in 10 million parts of water against first and second instar larvae of C. discalis Williston in water and obtained a 72 per cent mortality in 48 hours. One part of DDT in 5 million parts of water caused a mortality of 98 per cent in 48 hours.

A .035 per cent pyrethrum - kerosene emulsion used by Bailey (2) and mixed in the proportion of 1 quart of the emulsion to 7 - 8 quarts of water and lightly soaked into the soil gave excellent results. Within 5 minutes of application larvae of T. nigrovittatus Macquart began to appear on the surface where

they died a few minutes later. However Bailey does not consider this a practical control larvicide for the plots treated.

Adults - Methoxychlor, DDT, Toxaphene, and chlordane were tested independently in a mixture of cyclohexanone and No. 1 fuel oil by Howell et al (13). Applications were from the air and consisted of spraying 10-acre plots at the rate of 2 pounds of the chemical per acre. The effectiveness of the materials was determined by counting flies attacking draft horses led through the test plots 1 day before spraying and again 1, 2, 3, 5 and 7 days after treatment. The results appeared to be somewhat erratic and no appreciable effect on fly populations could be demonstrated for any of the insecticides.

Gjullin (8) sprayed cattle with 2- and 4- per cent emulsions made from a stock emulsion containing 25 per cent DDT, 68 per cent xylene and 7 per cent Triton X-100. Application of $\frac{1}{2}$ gallon per animal did not noticeably reduce the numbers of flies attacking the cows. In laboratory tests flies that were confined for 2 minutes in glass jars coated with a 2 per cent DDT emulsion and then transferred to clean jars were killed in 8 hours, while those confined in coated jars for 10 minutes and then transferred, were killed in 4 hours. There is no mention made however, of the amount of DDT per unit area of glass, which, of course, is of prime importance.

THE UNIVERSITY OF CHICAGO
DIVISION OF THE PHYSICAL SCIENCES

DEPARTMENT OF CHEMISTRY

REPORT OF THE RESEARCH GROUP ON
THE CHEMISTRY OF THE CARBON

BY
J. H. HARRIS, JR.

AND
J. H. HARRIS, JR.

CHICAGO, ILLINOIS

1955

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Portchinsky (24) reported two effective methods of reducing adult numbers.

i. By spreading kerosene over the surfaces of selected pools. As the male adults skimmed the surface and dipped their proboscides in for water, the abdomens also came in contact with the kerosene. Death apparently was caused in this manner by poisoning or suffocation.

ii. By coating a black shield with a sticky material and carrying it along paths in known adult localities. The adults were attracted in large numbers to the shield.

The practice of coating stakes with various non-drying adhesives to obtain data on populations has been reported by Roth and Lindquist (26) and presumably could be used also as a control measure.

1.3. MECHANICAL

Segal (27), in discussing Bourgault's trap (6) for cattle flies suggests that the trap could be effectively used against horseflies. Primarily designed to rid cattle of the nuisance of Stomoxys in Mauritius, the trap consists of:-

i. A darkened, partitioned building with entrance and exit doors.

ii. A brush of leaves and branches.

iii. A lighted chamber into which the flies are attracted after they are brushed off the animal, and where they

are afterwards destroyed. Ten minutes are said to be sufficient for a herd of 100 oxen to enter the building, pass through the brushes, and come out ^{of} the trap at the other end freed of flies. The trap, rather than being constructed near a barn would be set in a convenient location in a pasture.

2. POPULATION AND ABUNDANCE STUDIES

Larvae - Using the pyrethrum - kerosene mixture referred to under chemical control Bailey (2) estimated the larval population of T. nigrovittatus from a salt marsh area in Massachusetts to be 22.6 per square yard. The population of the young larvae was greater than that of the mature larvae. Roth and Lindquist (26), by sieving soil and mud from selected areas, obtained various results ranging from 0 to 133 per square foot. Larval populations from the edge of a small stream in New York state were estimated by Tashiro and Schwardt (30) by the use of a sod-drying apparatus were as high as 120 per square yard. An area of sod 2 yards square and 3 inches thick, taken from under a canopy of trees in perpetually saturated soil, but without standing water, yielded a total of 187 larvae of species of both Chrysops and Tabanus. Logothetis and Schwardt (15) dried sods on wire racks suspended over pans of water. As the sods dried, the larvae fell into the pans. Using this method they found 1 larva of T. quinquevittatus to 2 square feet.

Adult - Abundance was estimated by Roth and Lindquist (26) by counting the numbers obtained by swinging a standard size insect net over the head 4 times after which 3 forward steps were taken. This procedure was repeated for 2 minutes during which time 32 swings of the net were made. Further observations were made by counting the flies captured on stakes coated with the non-drying adhesives Tanglefoot, Deadline and Hercolyn. The population of T. vicarius Walk. in New York state as estimated by Logothetis and Schwardt (15) was 20,000 per acre of pasture. They arrive at this figure through insectary rearings in which they obtained a 1:1 sex ratio.

3. REARING TECHNIQUE

In order to observe the larval moults, Marchand (16) reared larvae of T. lineola Fab. in test tubes containing a rolled sheet of filter paper somewhat less than the length of the tube and filled with water to about $\frac{1}{2}$ - 1 inch. Cheesecloth fastened to the top of the test tube served as a stopper. Pupations occurred in the upper portion of the test tube. Jones and Bradley (14) successfully reared the larvae in moist sand in small glass jars. Philip (19) used damp soil, damp sand, and a modification of Marchand's method i.e. used damp paper towelling instead of filter paper in the test tube. Fruit jars with galvanized wire gauze soldered into the ring have also proved

satisfactory (34); The larvae being kept in the moist environment in which they were found.

C. vittata Wied. was reared from egg to adult by keeping the larvae in mud in a tilted pan so that a moisture gradient ranging from moist mud from which water could not be expressed to complete submergence, was obtained (15).

Larvae can live on a large variety of food. Marchand (16) fed larvae of T. lineola Fab. on earthworms and small pieces of meat. Hatton (10) fed fly maggots to larvae every 2-3 days but does not indicate the ration each tabanid larva received. Other observers have used mosquito larvae and small crustaceans as larval food. Cameron (5) found that species of Chrysops could be reared successfully simply by keeping the larvae in soil rich in decaying organic material while Logothetis and Schwardt (15) observed Chrysops vittata feeding on crane fly larvae and blow fly maggots.

4. HABITS AND BEHAVIOR

The egg laying habits are extremely variable. Roth and Lindquist (26) located egg masses of C. discalis on sedges, wire gauze, glass, card board, and other objects placed in the water near the shore. Unpainted wooden stakes and stakes painted red also proved to be excellent oviposition sites. Hatton (10) found egg masses on water parsnip leaves, 7 inches above the water. These hatched when kept on moist moss. Webb and Wells (34)

were not successful in obtaining egg masses from T. phaenops O.S. in a large cage in which a calf was also enclosed. The adults, previously placed inside, occupied all their time attempting to escape. However eggs were obtained using a smaller cage consisting of a pan 14 by 11 by 4 inches with a cheesecloth tent covering 18 inches high. Mud, water and vegetation were placed in the pan; the flies ovipositing on the vegetation. Eggs were also found on bulrush stems, coarse grasses, trunks of small trees, overhanging timbers and even on a barbed wire fence. Chrysops eggs were found on the large leaves of an aquatic plant. The leaves were flat on the water surface. Stone (29) has found tabanid eggs on rocks projecting from a flowing stream.

Immature stages of T. vicarious can grow to maturity and emerge in pastures and meadows and in New York these places form the normal habitat (15). This, of course, is quite unusual as a larval habitat.

Mating is not frequently observed. It almost always occurs in the morning, from before sunrise to about 9 o'clock. When the mating pair is at rest, the male hangs inert, and when in the air, the male does the flying (29). Webb and Wells (34) also observed mating in the early morning. The flies flying very rapidly in copula about 8 feet above the ground and then settling on a stem of grass for a few seconds before separating and flying

away. Hagman et al (9) observed mating to occur generally from 2-5 feet above ground and occasionally as high as 20 feet. The male struck the female and connection was made in flight, after which the pair attached to a leaf, one holding firm while the other hung motionless below. These observations by Hagman et al were made during the evening which appears to be an unusual time of day for mating to occur.

Stone (29) states that the adults are lovers of sunlight, warmth, and moisture and are possessed of a 'strong positive phototropism'. They are attracted to moving objects such as automobiles and trains, and will also collect around, and in, a standing automobile. This behaviour was also noted by Twinn et al (32). Stone (29) mentions further that the adults are attracted to water as evidenced by the large numbers which are frequently seen at the water's edge.

Males of T. giganteus De Geer were seen by Hagman et al (9) hovering along the edge of a country road around sundown and remaining active well into twilight. This habit appeared to be restricted to the period just before darkness when the temperature was falling, and the author suggests that its purpose may have been to maintain the body temperature of the males sufficiently to enable them to make the rapid flights necessary to overtake the females at this time.

Adult activity was found by Tashiro and Schwardt (30) to be practically negligible below 72° F. They observed the

greatest activity between 72°F and the 'high 80's' regardless of humidity conditions. In the 90's activity was somewhat reduced and, during gusts of wind, ceased entirely. Adults were very active during a storm front with an overcast sky and high humidity. Uvarov (33) endeavored to correlate adult activity in many groups of insects with weather phenomena. He discusses at length the various factors effecting activity and concludes that most activities are influenced by a combination of several meteorological factors and it is impossible to explain the activities by a single one.

The volume of blood which various species can engorge has been estimated by many authors. Thus Cameron (5) estimates that T. septentrionalis Loew becomes completely engorged with 0.2 cc. of blood in 10 minutes. He further estimates that on a day when the adults are active throughout, cattle would lose about 100 cc's. if bitten to engorgement 50 times per hour. Tashiro and Schwardt (30) weighed specimens of T. quinquevittatus Wiedemann immediately after blood meals had been taken and calculated each specimen to take .074 cc. of blood. At 90 bites per hour, in an 8 or 9-hour day, each head of cattle would lose approximately 53 cc. The same authors found that T. sulcifrons Macquart could engorge .359 cc. and indicate that the loss per head of cattle during a period of 8 or 9 hours would be about 115 cc. if the cattle were receiving 40 bites per

hour. Incorrect readings will be obtained unless the specimens are weighed immediately following engorgement since the assimilation leading to excretion of the blood is so rapid. The authors suggest that the loss of blood is probably greater than the volume indicated since they do not include blood that drips or oozes from the wound after the fly leaves.

Philip (19) estimates the blood loss per day per animal could be as high as 300 cc.. Webb and Wells (34) observed the feeding of T. phaenops and estimated conservatively that if an animal was subjected to the constant biting of 25 - 30 flies for 6 hours (each fly becoming engorged in 8-10 minutes), 100 cc. of blood would be taken.

5. TAXONOMY

In a recent publication Philip (21) has done away with the genus Tabanus sens. lat. which, to his mind, formed a convenient "catch-all". Tabanus Linn. sens. stric. now refers to that group of the tribe Tabanini having a normal flagellum with 4 distinct annuli (in doubtful cases, abdomen without sublateral rows of spots); vertex without distinct, denuded ocelligerous tubercle, eyes bare, or if sparsely hairy, with more than one purple band (See Chapter 2) and the abdomen may have a uniform, pale, mid dorsal stripe; front of female with a broad

basal callosity; annular hair, if present, very inconspicuous; body and wings varicolored (when entirely black, over 15 mm. in length).

The author, in presenting this paper, has adopted Philip's nomenclature and all northern species dealt with, and previously placed in Tabanus sens. lat., have been removed and placed in the genus Hybomitra End. This genus, also in the tribe Tabanini, refers to the group having a normal flagellum with 4 distinct annuli (in doubtful cases, abdomen without sublateral rows of spots); vertex of the female with a distinct, denuded ocelligerous tubercle, or, in the male, with an elevated, anteriorly shining tubercle (in doubtful cases eyes are densely pilose). Front of female variable, but the basal calosity correspondingly broad; eyes usually distinctly pilose; eye facets of male relatively undifferentiated; scutellum usually dark.

Pechuman (18) indicates that further work is required on the immature stages of C. carbonaria Walk. and C. mitis O.S. because many workers suspect that these two species are not distinct although the larval characters are said to show that they are different. He also points out the similarity between the adults of C. carbonaria, C. celer O.S. and C. excitans Walk.

Stone (28) pointed out the similarity between the females of H. gracilipalpis Hine and H. cristatus Curran and also the similarity between the female of H. gracilipalpis and

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H. affinis Kby. Hine (11) noticed this similarity between the last two but pointed out that gracilipalpis, although suggestive of affinis, had more slender palpi, the front was narrower, the frontal callosity quite different, the average size somewhat smaller, and the general form less elongate.

The male of H. septentrionalis Loew was unknown to Stone (28) and not sufficiently well described to permit distinction between it and related species.

Philip (20) noted the similarity between C. furcatus Walk., C. lupus Whit., C. coloradensis Big., C. proclivis O.S. , and C. surdus O.S.. The group is a heterogeneous one having superficial resemblance in the pattern seen on the abdomen, wing, or eyes, together with infuscation of cheeks and parts of the face in all but coloradensis. A darker ^{form} ~~species~~ of C. furcatus is also present in the material studied by Philip.

Taxonomy

1. LARVAE

For purposes of description, Marchand (17) considers that the following points should be noted:-

- i. Abdominal markings
- ii. Striae
- iii. Characteristics of 'prolegs' (Obviously referring to the ventral proleg-like tubercles)
- iv. Length of siphon tube
- v. Structure of antennae

In the hope that differentiating characters in the larvae would be retained in the last larval exuvium, as in the case of mosquitoes, all last instar exuviae from insectary reared material were retained. The above characters are not retained, however, and occur only in the fully mature larvae. Taxonomic work with larvae could be done either by rearing described larvae to identifiable adults or by rearing larvae from the eggs of identified females. The latter would appear to be the more suitable. This would be possible if a method could be devised whereby females would lay eggs in captivity.

2. PUPAE

Marchand (17) has also listed characters which he considers of taxonomic importance in the pupae. These are:-

- i. Length of antennal sheath.
- ii. Character of the thoracic spiracle, especially the inner margin.
- iii. Length of the hairs on the abdomen.
- iv. Size and shape of the spines on the 8th segment.

It is possible to distinguish between the male and female pupae of both Chrysops and Hybomitra spp.. In the female, the large, ribbed anal tubercle which is present in the male, is very much reduced, (Fig. 1). The fringe of spines ventral to the anal tubercle which is continuous in the male, is divided in the female.

Cämeron (5) has illustrated pupal asters of a number of Chrysops and Hybomitra spp.. A careful examination of the pupal skins obtained from insectary rearing reveals that the size and shape of pupal asters are not in themselves of taxonomic value. To support this statement a series of line drawings were made illustrating pupal asters of various species. The results are shown in Figs. 1 to 9 inclusive. Variation exists not only within a species but also similarities between species so that it is unwise to base identification on pupal asters alone. As an example, there is a wide variation in relative size, shape and position in the pupal rays of H. septentrionalis males and females and C. nigripes males, as shown in Figs. 2, 3 and 9 respectively.

Pupal asters of other species are illustrated in Figs. 4 to 8 inclusive. The gnarled appearance of the rays in the male of A. ohioensis may be of taxonomic significance but since only one male and one female was reared, further evidence is needed. The rays of the female are not gnarled. However, the immature stages of both the male and female of this species are white in color and easily distinguishable from the immature stages of Chrysops and Hybomitra spp. . The abdominal segments do not show such conspicuous bands as species in the other genera. In point of fact, these larvae can be easily mistaken for any one of numerous, pale dipterous larvae since they do not conform in color or general appearance with the tabanid larvae usually encountered in the north.

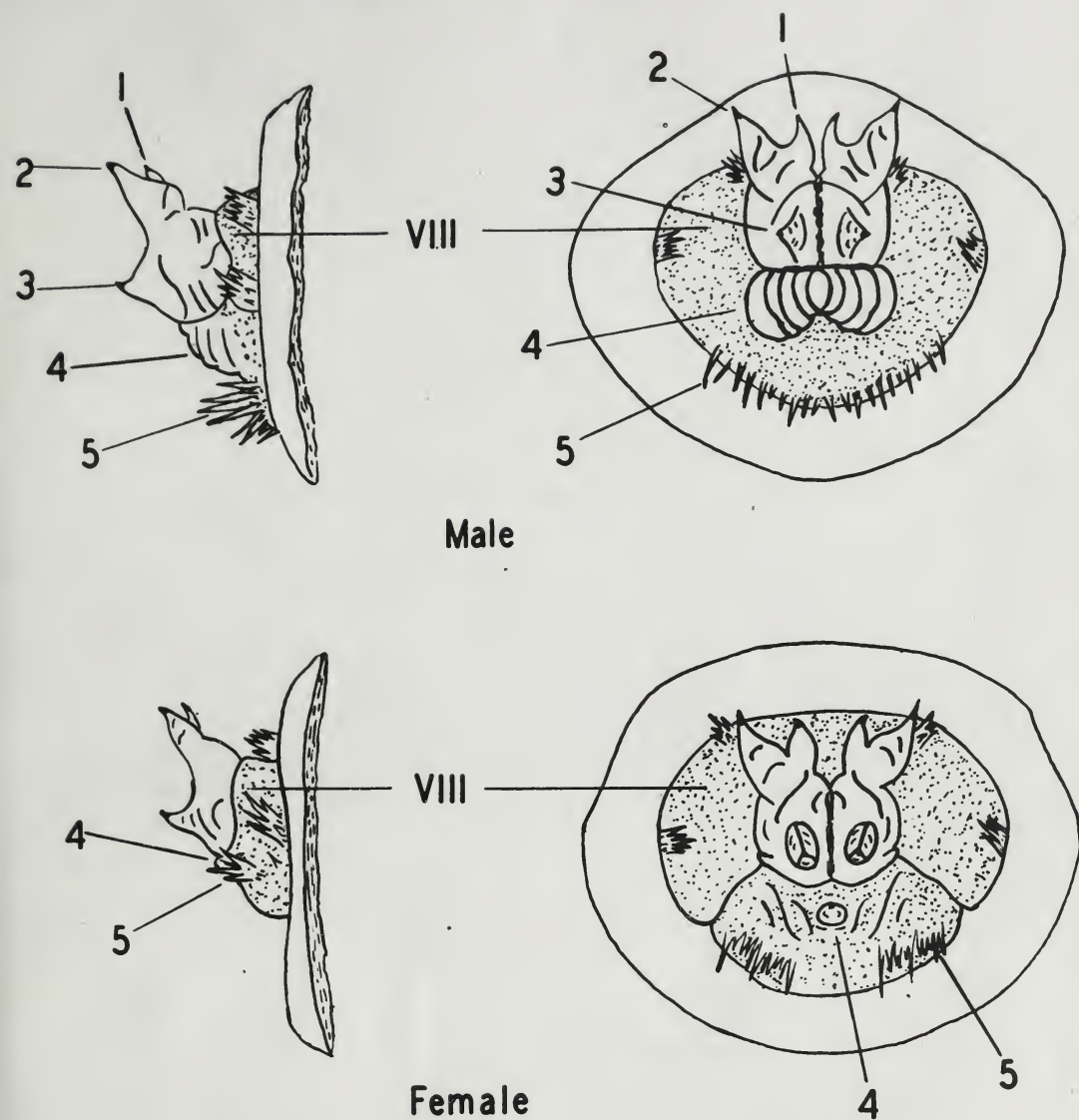
3. ADULTS

To the student of the Tabanidae, the works of Stone (28) and Brennan (4) are indispensable. The identification of Hybomitra spp. (Tabaninae) and Chrysops spp. (Pangoniinae) respectively have been made with the keys and descriptions of these authors. Invaluable contributions to the taxonomy of this group have also been made by Philip (19, 20, 21, 23).

Little difficulty was encountered in separating the species of Chrysops although 2 specimens of C. frigida O.S. from field cages were considerably darker than usual.

Separating the males of Hybomitra spp. proved to be difficult. This is not surprising in view of the fact that the

PUPAL ASTERS

FIG. 1 *H. septentrionalis*

1. Dorso—median ray
2. Dorso—lateral ray
3. Ventro—lateral ray
4. Anal tubercle
5. Anal fringe

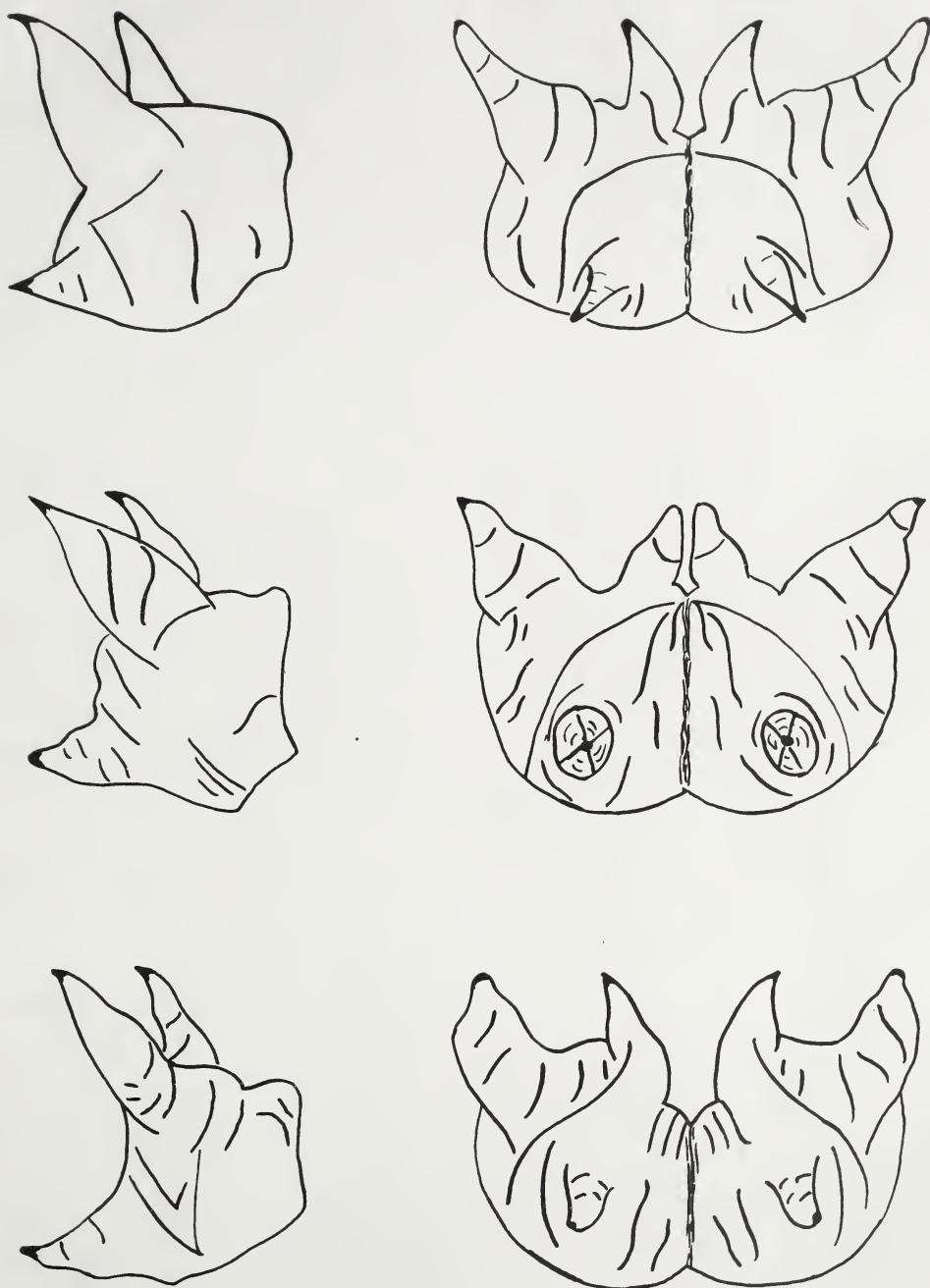


FIG. 2 *H. septentrionalis* Males

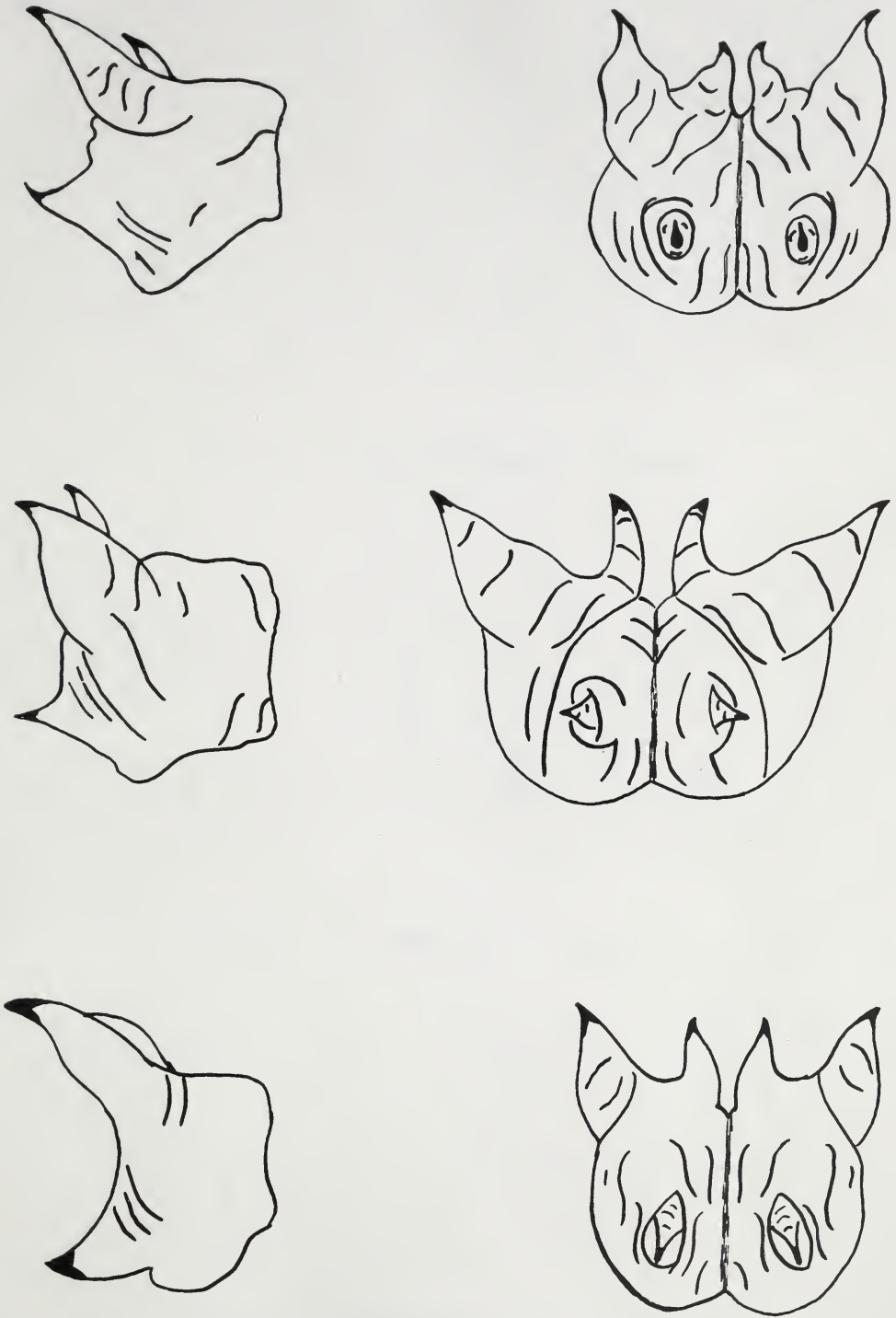


FIG. 3 *H. septentrionalis* Females



FIG. 4 *H. gracilipalpis* Female



FIG. 5 *H. affinis* Male

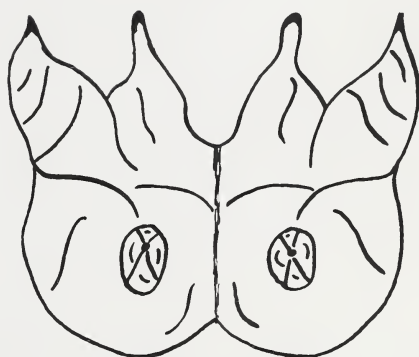
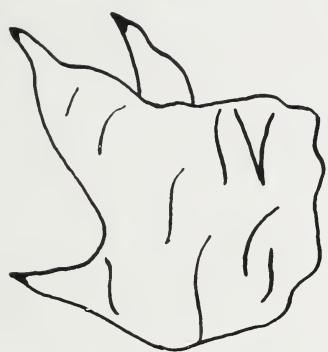


FIG. 6 *Hybomitra* sp. Female





Female



Female



Male

FIG. 7

H. itasca



Male



Female

FIG. 8 *A. ohioensis*



FIG. 9

C. nigripes

Males

males of the Tabanidae are seldom seen and still more rarely captured. Reference material is scanty.

The separation of the females of H. affinis and H. gracilipalpis is also difficult. In an effort to obtain a linear measurement ratio which might be used in separating the females of these two species, measurements were made of the length of the hind tibia, width of the head, length of third antennal segment and length of discal cell. Various ratios were computed from these measurements but none were significantly different between the species. During the season, however, specimens which were considered to be H. gracilipalpis owing to their small size, were dissected and egg counts recorded. The mean of these differed from the mean egg count of typical H. affinis by some 40 percent, (Table 2, P.73). All Hybomitra spp. have beautifully colored eyes in life but the coloration quickly fades with death and is seen only occasionally as dull, purplish, horizontal bars in pinned specimens. This coloration may be of taxonomic importance in differentiating between the two species. Throughout this paper the affinis - gracilipalpis complex has been considered under the general heading of H. affinis.

All specimens which were obtained from insectary rearings and field emergences were identified by the author and were confirmed or corrected by Mr. G. E. Shewell. The

following is extracted from a memorandum by Mr. Shewell,
dated December 14, 1949:

'It is not a bit surprising that Mr. Miller had trouble with the males of Hybomitra. No one has yet accumulated enough material of this sex to construct a good key, and it is to be noted that neither Stone nor Philip (Can. Ent. 1937) had enough material to feel justified in including septentrionalis Lw. in their keys. I am reasonably sure that most of Mr. Miller's males are this species. I have provisionally recognized 5 species among the males, as follows:-

1. septentrionalis. Many specimens. A few are marked with a query due to differences in size and color pattern of the abdomen.
2. itasca Philip (#216) This with a query since the species is rare and the male has never been recognized.
3. affinis Kby. (#293, Cl6). No doubt about these.
4. Tabanus sp. (#344, D). I am not at all satisfied that these are septentrionalis, although they are O.K. for size.
5. Tabanus sp. (C 14). Definitely another species.

I have considered what these unnamed species might be having regard to our knowledge of the females occurring in the area, but can reach no conclusion at present. I am quite certain that gracilipalpis Hine is not among the males in the collection. We have proof that the male of this species is the same as that described by Curran as cristatus (crested). It is characterized

by a very distinct crest of long black hairs on the mid-line of abdominal segments 2-4. Other males in this group have only a few erect long black hairs on the second segment. I am also sure that metabolus Mc.D. is not represented.

There is no doubt that, at present, the males in this group constitute a very difficult taxonomic problem.'

Biology

1. LARVAE

The larvae of the tabanid species under observation at Churchill were similar in appearance to those described by Marchand (16). That is, they were elongate, cylindrical, slender, tapering at both ends, and capable of contraction and extension. The body consists of a head and 3 thoracic and 9 abdominal segments, the last segment being very short. The larvae are eucephalous, with head well developed but small and withdrawn, bearing the 3-jointed antennae just above the palpi, the basal joint being short, the others of varying length. They are metapneustic, usually aquatic or semi-aquatic, and occasionally terrestrial.

1.1. COLLECTING METHODS

The search for tabanid larvae in the field began June 1st., but owing to very cold weather had to be abandoned in favor of a procedure which produced excellent results with less discomfort. Vegetative ground cover collected from suspected larval habitats was sorted over carefully in the laboratory. This vegetative ground cover, composed mainly of mosses, was dumped on a long table covered with galvanized iron, where it was possible to pick it over in comparative comfort. All specimens taken in this manner were retained and the bulk

of the picked-over moss recorded in order to obtain a figure for the number of larvae present per acre of habitat.

In the northern latitudes frost leaves the ground surface very slowly and persists almost throughout the month of June. Permafrost, of course, is present the year round.

The northern species of Tabanidae overwinter in the larval stage; the vast majority not more than 2 to 3 inches below the surface of the vegetation. Our search during this period was confined, therefore, to this top 3 inches. Below this depth everything was frozen but it was possible to chop out fairly large pieces of vegetation and allow them to thaw out in the laboratory. Tabanid larvae were found under such conditions but in very small numbers and much time was required chopping and thawing so this procedure was discontinued. Stone (28), in an endeavor to simulate natural conditions, attempted to rear larvae that he had frozen in their environment. As a result of his experiment he states that the larvae cannot survive in frozen soil, at least if it is moist. This statement does not hold true for the larvae of northern species.

1.2. SELECTED SEARCH AREAS

Experiences in 1948 indicated that obtaining a large collection for rearing purposes would take much time and effort. It was planned to have at least 300 larvae in rearing at the insectary by the middle of June.

All suspected larval habitats were searched and whilst many of these proved to be almost without life, it was generally possible to find one or two tabanid larvae.

The first larva found was on June 1st. A small hummock approximately 8 inches in height was sticking up through the icy water in the trail of a tracked vehicle. The trail skirted the edge of a group of spruce and larch, and during the previous summer and fall was dampened only occasionally by light rainfall. The nearest permanent body of water was a small pool 100 yards away from the trail. A green larva, approximately one inch long, was found within the hummock when the latter was accidentally kicked over, and the larva was seen lying on top of the ice.

Searching was continued in a random manner until heavily populated areas were located. Where larvae were found at the rate of 10 to 15 per man per day, the population was considered to be unusually large. During the summer 4 such areas were located and practically all the larvae taken for rearing purposes came from these areas, which are described below.

i. A rather large pool approximately 100 yards long and 15 yards wide at point 926027 (Figs. ¹⁰⁹11). Depth did not exceed 3 feet. During the early part of June the bottom of the pool was covered with dead leaves, twigs, moss, and

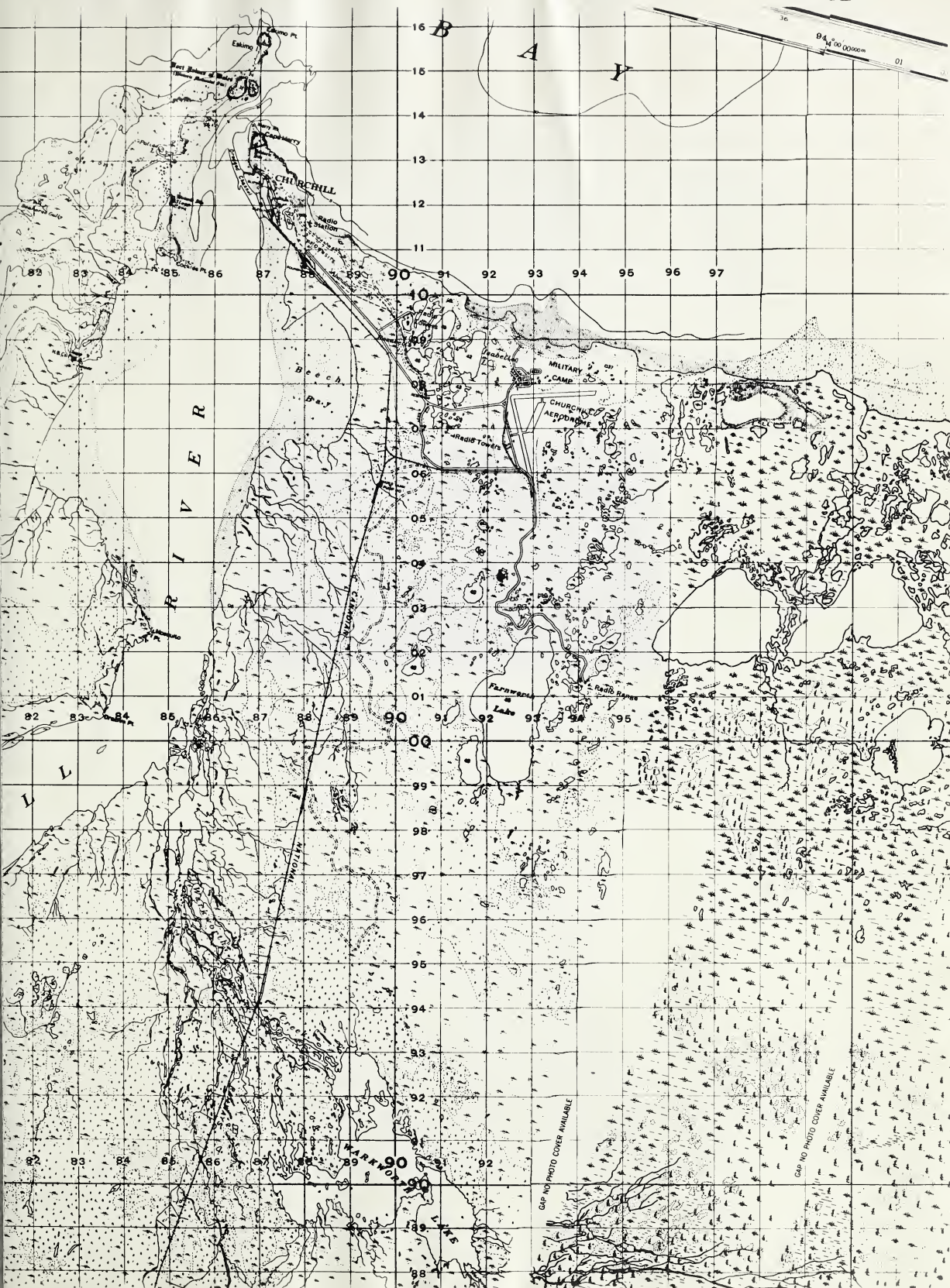


FIG. 10



Fig. 11. No. 1 Search Area for Larvae

decaying organic matter to a mean depth of about 4 inches. Below this, the ground was frozen. Quantities of this bottom material were taken from the pool to the laboratory where it was carefully worked over. This location proved to be the least productive of the four search areas and was soon abandoned.

ii. An area of approximately one acre of rather open tundra meadow surrounded by a border of spruce and larch trees 16 - 20 feet high. Point 904065 (Fig. 12). Sparse arctic willow and small patches of young spruce and larch, not exceeding 4 feet in height grew here. Previously the whole area had been flooded with the spring thaw with only the elevated knolls and hummocks left visible, but on June 6, when the first search was conducted in this area, only small pools remained, although the ground everywhere was saturated.

In this area there were 2 types of moss, one of a compact, hard-packed growth, and a second, loosely woven moss. No larvae were found in the former, possibly because of its physical nature.

The second type of moss proved to be the most productive habitat encountered. Each searcher averaged one larva every 5 minutes on a good day. Seldom, however, could this average be maintained for longer than 2 hours, and on only one occasion did one of the party exceed 40 larvae in a day's



Fig. 12. No. 2 Search Area for Larvae

searching. It is difficult to explain how two men standing not 10 feet apart, each with equally good eyesight, searching in identical habitats, can produce such different results. In one instance one of the party picked up 22 larvae in a morning while his co-worker, working in the same area found none.

By June 10th the weather had warmed considerably and it was possible to work outside without discomfort. On this date 3 searchers found 105 larvae in 5 hours in this area, a performance which was unequalled subsequently throughout the season.

iii. Point 904068 (Fig. 13) was the next area searched. It comprised an area of approximately one acre of low-lying grassy tundra interspersed with the occasional willow clump and single larch or spruce tree. Small pools were still present from the spring thaw and the edges and bottoms of these pools were covered with moss and sedges to a height of 12 - 15 inches.

Larvae were found in all sorts of situations. Some were about one half inch from the surface and others 3-4 inches below the surface. The layer of moss was approximately 3 inches deep, but varied, and occasionally was as much as 5 inches. This moss covered a rotting, mucky bottom which, on June 10th, was still icy. By peeling off this top layer of moss and turning a handful upside down, numerous larvae were found sticking half way out.



Fig. 13. No. 3 Search Area for Larvae

Most larvae were found where the moss was just projecting 2-3 inches out of the pools. The larvae were then found close to the water level. Small areas covered with a foul smelling scum were also subjected to a thorough searching and although many rat-tailed maggots (Syrphidae) were found, these areas were devoid of immature stages of the tabanids. Very seldom, throughout the season, were larvae found in anything other than a fresh, living medium. However, one larva of a Hybomitra sp. was found which had passed the winter in the root of an aquatic plant. The plant had decomposed to such an extent as to make identification impossible.

Many of the pools in the north sustain almost no visible fauna. These are the pools, the bottoms of which consist of a coal-black, decaying organic muck with a most disagreeable odor. Absence of fauna is probably attributable to physico-chemical factors. One such pool gave a p H as low as 4.5.

iv. This last area was the largest one searched. It consisted of about 5 acres of stagnant muskeg area and interconnected pools surrounding point 924025 (Fig. 14) and bordered by a heavy stand of spruce and larch. To the south a bank rose steeply at an angle of 60 degrees to approximately 3 feet above the water level. There was a transition from loosely packed moss, to tightly packed moss



Fig. 14. No. 4 Search Area for Larvae

and decaying roots and leaves covered with an inch of reindeer moss. Larvae were found in all these situations.

Many larvae were found on the bank along the south margin. Those at the water's edge were small and generally the size increased with increasing distance from the water. Very large larvae were found some distance from the water under the reindeer moss which was dry and peeled off in a layer. The decaying vegetation immediately below this was only slightly damp.

1.3. POPULATIONS

Larval populations of areas i. and iii. were estimated using the following method:-

All the material worked over in the laboratory was retained in a large garbage pail with a capacity of 0.16 cubic yards and it was thus possible to arrive at a figure for the number of larvae per cubic yard. The material was packed as much as possible since the bulk was obviously increased considerably when pulling the moss apart.

From area i. 20 larvae were obtained by picking over 0.16 cubic yards of moss, etc.. This would indicate a larval population of 20 for an area of 1.44 square yards to a depth of 4 inches. This is equivalent to approximately 67,200 larvae per acre of pool bottom.

From the same bulk of bottom material worked over, i.e., 0.16 cubic yards, 60 tipulid larvae were found which



Fig. 15. Method of Collecting and Picking over
Vegetation for Larval Population Estimates

would give an approximate population of 201,600 per acre of pool bottom. It is significant to note that almost invariably larvae of this tipulid species were found in the same habitat as the tabanid larvae, particularly those of the Hybomitra spp..

Using the same method the larva^le population in area iii. was estimated at 200,900 per acre. (For comparative data 2 months later see page 43)

1.4. OBSERVATIONS AND DISCUSSIONS

1. Practically every larva found appeared to be three quarters to fully grown. If our previous suspicion, that some of the species at least, had a two year term life cycle, was correct, smaller larvae should be found representing the brood of 1948, whilst the larger larvae which we were finding would represent the brood of 1947. At first glance then, it appeared that the northern species of Tabanidae enjoyed a one-year life cycle with the larvae reaching near maturity probably around the middle to the end of September and passing the winter in this stage. Subsequent records from insectary rearings and field observations throughout July and August proved that this supposition was erroneous and that certain species at least have a two-year life cycle. It would probably be more correct to say that the life cycle of these species is more than one year since the

possibility exists that 3 or 4 years may be required to complete development.

2. Larval colors ranged from creamy-yellow to leaf green, or to shades of brown. These various colors could arise from three possible causes, differences of:

- i. Nutrition
- ii. Age
- iii. Species

The first possibility was considered unlikely since several larvae, all different in color, could be found in a single environment. It was found in the insectary rearings that the color variations could be attributed to moulting in some instances, and in others, to a gradual color change with age.

Subsequent work with the reared material indicates that color is not specific: different species often having the same color and one species having varying colors.

The most abundant leaf-green larvae blend so beautifully with the green moss where they are usually found that it is possible for even a keen observer to miss them. This coloration may have protective significance. With the possible exception of stratiomyid and tipulid larvae, which are dark in color, all other aquatic or semi-aquatic larvae encountered were pale yellow and easily seen.

3. All larvae had been found within 2-4 inches of the surface in the thawed vegetation. They certainly could not have worked through the frozen moss even if they were active at that time of year and therefore they must have passed the winter in the top 4 inches. Larvae should be easier to find in the spring than in the fall since they are then concentrated near the surface. Observations showed that, as the lower layer of vegetation begins to thaw and dry out, the larvae go deeper in search of food and moisture. Towards the end of the summer larvae were becoming increasingly difficult to find and many were taken 6-8 inches below the surface in more moist conditions than the top 4 inches afforded.

4. As already mentioned, the larvae population in iii. was estimated at 200,900 during the first week in June. On the 19th of August, over two months later the same area had an estimated population of only 35,500 and many of these were found 6-8 inches below the surface. The main reason for this sharp decline, of course, was the fact that by August 19th the 1949 brood of larvae had not hatched, and also by that date, all the flies for the season had emerged. The only larvae left in the ground then, were those which had hatched in the fall of 1948 and would emerge as adults during the summer of 1950 (assuming a two-year life cycle only). Other contributory factors which might account for such a notable decline are:-

i. Predators (See Chapter on insectary rearings).

ii. Cannibalism. The strong cannibalistic tendency would account for the absence of any concentrations of Hybomitra larvae in the field.

iii. Other natural mortality.

5. By June 10th warmer weather had excited the cannibalistic nature of the larvae of Hybomitra spp. in the insectary. Owing to a shortage of containers, about 35 Hybomitra spp. and Chrysops spp. larvae were placed in a single 4-oz. specimen jar and within a matter of 2 hours, no less than 10 larvae had been completely devoured by the other larvae. Thereafter all larvae were placed in corked, individual, shell vials 16 x 50 mms. with a small amount of moss. This technique proved completely satisfactory and eliminated losses due to cannibalism.

6. During the early part of June tabanid larvae showed little inclination towards food. Hybomitra spp. larvae, usually voracious eaters, refused snails, slugs, tipulid, and other dipterous larvae and exhibited none of their well known cannibalistic tendencies. Five or six larvae could be left in a small jar at this time of the year without any danger of cannibalism.

7. On two separate occasions while searching for larvae the observer received bites from them, and on each occasion the skin was pierced on the inside of the ^{finger} ~~finger~~. A sharp stinging sensation was felt which persisted for 20 minutes.

No blood was drawn and no swelling occurred.

8. Slides were made periodically of larva^l gut contents and submitted to Dr. E. O. Hughes, botanist from Oklahoma University, in an effort to determine whether or not algae formed any part of the larva's diet. Usually all the food was found in the hind gut and consisted of a rather hard, compact, brown pellet. When this pellet was macerated and viewed under a microscope, only numerous small oil globules were discernable. No micro flora could be recognized. Numerous dissections were made of both living and preserved material and examined but no structurally recognizable material was found.

9. On June 10th a large Hybomitra sp. larva was found which appeared to have a growth on its anterior segments. On closer examination however, this 'growth' was seen to be a small clam (Sphaeriidae) 1.5 mm. in length, which had attached itself firmly to the larva's integument. No amount of twisting and rolling could dislodge the clam. Even when placed in 70 per cent alcohol it held on tenaciously and only when it had died was its grip released.

10. Immature stages of the following orders were found associated in the same habitat with tabanid larvae:

Diptera - Mainly Tipulidae, but also

common were rat-tailed maggots

(Syrphidae), Stratiomyidae, Dolichopidae,

Ephydridae, Chironomidae and many
cyclorrhaphous larvae and puparia.

Coleoptera - Mainly Dytiscidae

Odonata - Libellulidae and Aeschnidae.

2. PUPAE

The following description is taken partially from Marchand (17) and is supplemented by an examination of the pupal cases of H. septentrionalis.

The pupae of tabanids strongly resemble the obdect lepidopterous pupae having wing and leg cases firmly attached to the body. The pupa is subcylindrical, abruptly pointed or rounded anteriorly, and tapering somewhat posteriorly; it is generally yellow to ferrugineous brown. The antennal sheaths are firmly appressed, pointing outward. The segments of the thorax are indistinct; the mesothorax bears the large, raised, ear-shaped spiracular openings. Two pairs of small tubercles, each with a central hair, are situated antero-ventrally on the thorax, and a single similar pair, antero-dorsally. The abdominal segments are distinct and finely wrinkled, and on each segment there is a pair of small tubercles situated on the median lines of the lateral areas, near the anterior margin of each segment. The segments are about equal in length and have one or more fringes of hairs which encircle the segment near the hind margin. These hairs are progressively longer from before backwards,

and are best developed on the 7th segment. The 8th segment is short, and is provided with 6 projecting rays or teeth and with a large anal tubercle. In the male the tubercle is ribbed, and bounded ventrally by a continuous fringe of strong spines; in the female the tubercle is very much reduced and the spines of the fringe are widely separated. The pupae of many of the larger species have, in addition, a pair of lateral, hand-shaped tufts of spines on the 8th segment, and also a similar, but smaller pair, situated dorso-ventrally.

2. 1. AREAS OF OCCURRENCE

Pupae, like larvae, were found in almost every conceivable situation but the following general remarks can be made.

Normally Hybomitra spp. pupae are found in drier habits than are the larvae, although in one instance a pupa was found in completely saturated conditions lying horizontally at the water level of a small area of moss in the middle of a pool. Such instances are extremely rare, however. Prior to pupation Hybomitra spp. larvae migrate considerable distances away from the pool's edge to a drier situation. Chrysops spp. larvae, on the other hand, pupate in the larval environment which normally is right on a pool's edge where saturated conditions exist. The majority of Chrysops spp. pupae were found in these locales, but here again, exceptions did occur

where the pupae were found in bone-dry areas.

On only one occasion was more than one Hybomitra sp. pupa found in the same handful of moss. Chrysops spp. pupae were invariably found in small groups ranging from 3 to 12 per square foot.

The first pupa was found in the field on June 21st and was a Hybomitra sp.. It was found $\frac{1}{4}$ of an inch below the surface of the moss in a vertical position.

Chrysops spp. pupae were found for the first time on June 27th.

Pupae were found in the field completely exposed on the surface of the vegetation. Others were found with only the thorax protruding, while others remained approximately $\frac{1}{4}$ of an inch below the surface. The last was the most general. It was observed in the insectary that just prior to emergence the pupa becomes fairly active, and by twisting and turning its body, slowly worms its way upward through the vegetation. The upward movement is aided materially by the presence of backward projecting bristles situated in the posterior border of the abdominal segments.

During the formation of the imagines, the pupae can be found in any position. Some are vertical, either end uppermost, some horizontal, and others inclined. Emergence apparently always takes place, however, from pupae

in a nearly vertical position, with the head uppermost, since practically all empty skins found were in this position.

2. 2. PHYSICAL CHARACTERISTICS

Newly formed pupae generally exhibit the same colors as the last instar larvae, which in Chrysops spp. range from light yellow to dark brown, and in Hybomitra spp., from leaf-green to dark steel grey. As the age of the pupa progresses, the thoracic region becomes darker first and this darker coloration slowly extends to the tip of the abdomen. At times the region of the wings become almost black.

Just prior to the emergence of adults of Chrysops spp. it is sometimes possible to see the eyes and eye coloration of the imago through the pupal case and thus determine the sex. This phenomenon could not be observed in Hybomitra spp. pupae.

3. ADULTS

Adult studies were considerably hampered during the entire season by inclement weather throughout July and August. Unlike the mosquitoes and blackflies, tabanids remain inactive during periods of sustained cloudiness and cold weather.

From field collections made in 1947 (32), 1948 (12) and by the author in 1949, the following tabanid species,

listed in order of occurrence, have been determined by Mr. G. E. Shewell of the Sytemmatic Unit, Division of Entomology:-

Hybomitra metabola McDunnough

H. zonalis Kby.

H. affinis Kby.

H. gracilipalpis Hine

H. septentrionalis Loew

H. hearlei Philip

H. sexfasciata Hine

Hybomitra sp. close to H. hinei Johnson

H. itasca Philip

Hybomitra sp. (new?)

Chrysops carbonaria Wlk.

C. furcata Wlk.

C. nigripes Zett.

C. frigida O.S.

C. mitis O.S.

Atylotus ohioensis Hine

H. hearlei, H. sexfasciata, the Hybomitra sp. close to H. hinei, and C. mitis were not taken in 1949. With the exception of C. mitis, these species are represented by only 1 or 2 specimens. C. mitis, which has not been taken

in the immediate Churchill area, was found to be quite abundant late in the season of 1948 in the forest 25 miles south of Churchill (32). In 1949 however, 3 new records were established, i.e. H. itasca, Hybomitra sp. (new?), and Atylotus ohioensis.

Dr. H. H. Schwardt identified H. illota O.S. and H. rhombica O.S. among the material collected at Churchill by McClure in 1936-37 (12). Neither species has since been recorded from this area.

H. nudus McDunnough, H. epistates O.S. Haematopota americana O.S. (1 specimen), and C. lupus Whitney (1 specimen) have been identified by Hine (11) among the material collected in Alaska in 1921 by Dr. Aldrich. H. epistates is one of the smaller species of the affinis group but somewhat variable in size. The sub arctic distribution of these species may be more extensive and it seems possible one or more of them might occur at Churchill.

Travis (31) collected 5 species of Chrysops and 9 species of Tabanus (Hybomitra) in Alaska but none of them commonly bit man.

Observation made during the 1948 and 1949 biting-fly season suggest that the species of Hybomitra attack man far more readily than those of Chrysops. This is contrary to the impression received by Twinn et al (32) during the season of 1947.

3. 1. NOTES ON THE SPECIES

H. metabola

Characteristically, H. metabola was the first tabanid adult to put in its appearance. In 1947 it was collected on July 5th, in 1948 on June 29th, and in 1949 on July 5th. Two specimens were taken on this date, one covered in pollen which was identified by a botanist as coming from either a species of Salix or of Dryas (Rosaceae).

The flight of H. metabola is relatively soundless and it is possible for this species to alight on an observer without first broadcasting its presence by the loud humming so characteristic of H. affinis, zonalis, and to a lesser degree, septentrionalis.

H. metabola was recorded as a dominant species only on one day, July 17th, when it was captured in large numbers around a dark green shed (Fig. 16). Thereafter the numbers began a gradual decline and the species was intermittently recorded until August 2nd.

H. metabola is not a serious pest in the north nor does it attack man persistently. Not once during the season did the observer receive a bite although every effort was made to 'induce' the species to take a blood meal. During the time the species was present in reasonably large numbers, moist limbs were left exposed and although a specimen would



Fig. 16 Shed used in Observing the Effects
 of Weather on Adult Activity

alight and wander around considerably, the skin was never pierced.

H. zonalis

This was the only species that appeared in greater numbers than in previous years. In size, H. zonalis is somewhat larger than H. affinis and these two species are the largest present in the Churchill area. The characteristic banding on the posterior margins of the abdominal segments of H. zonalis ranges from a creamy white to a bright golden yellow, and it is these markings that enable one to distinguish this species in the field from others present in the north.

In 1947 H. zonalis was captured on July 10th but was not taken thereafter, and in 1948 it appeared on July 4th and throughout the season a small number of specimens were observed. In 1949 the species put in its appearance on July 6th and rapidly became dominant. However, H. zonalis does not remain active long, and by July 17th it had become very scarce. The last observation of the species was recorded on July 20.

Like H. metabola, H. zonalis is not a serious pest of man in the north. No members of the group received any bites from either of these species.

Generally, all species of the Tabanidae are very furtive when they first appear, but as the season progresses they become more and more interested in the presence of man.

H. zonalis is the exception to this generality. The flight is erratic and noisy, even more so than that of H. affinis, and zonalis never remains alighted on man for more than a fraction of a second.

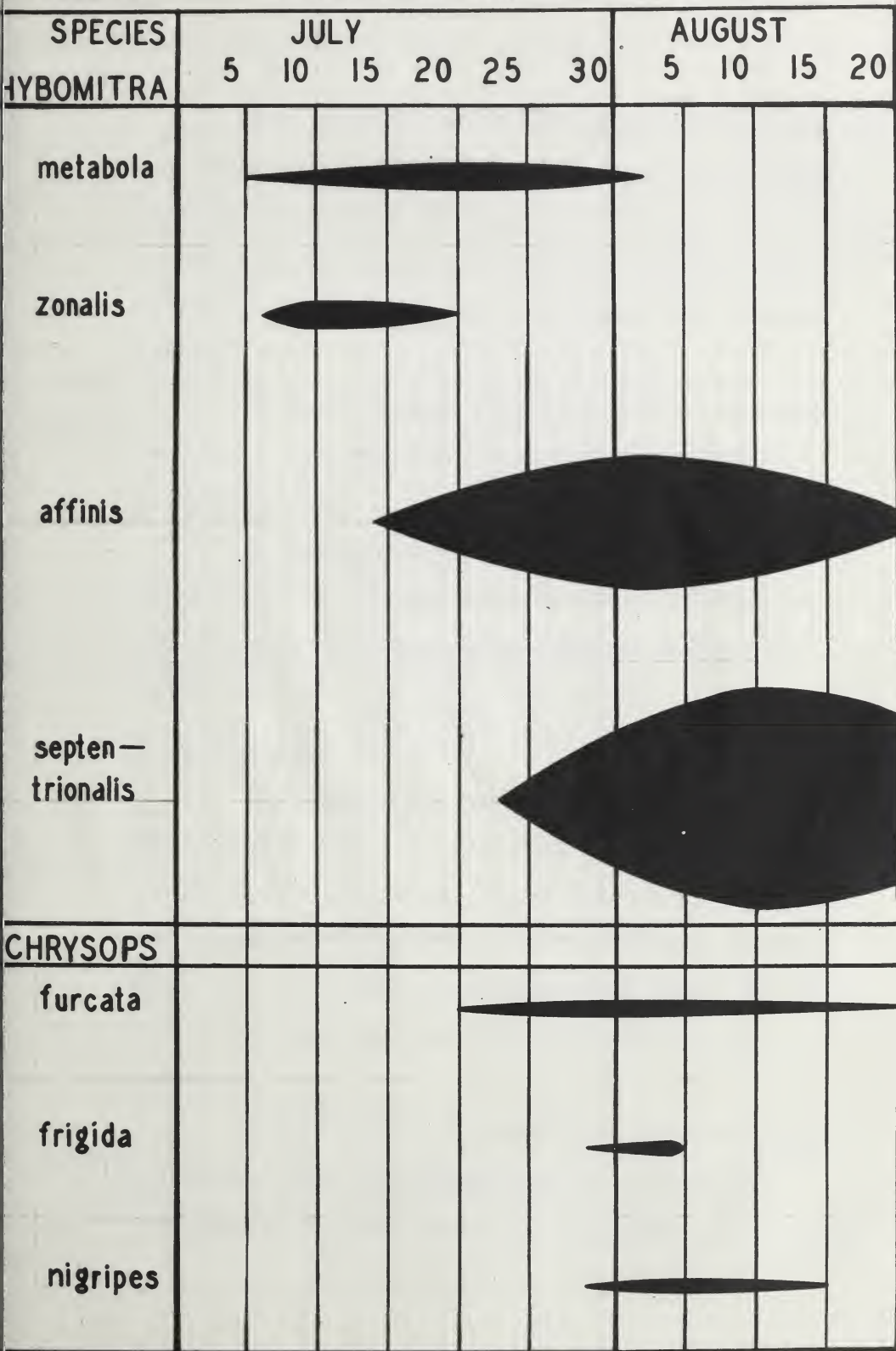
Many captures were effected simply by standing in front of a tar-papered frame and waving the net back and forth. As the flies circled the frame at great speeds it was sometimes possible to predict their next route and have the large insect net in readiness so that they flew into it. It was noted on several occasions that two flies were apparently playing a game of follow-the-leader. Often both (females) were captured at the same time. This behaviour is exhibited by affinis also, only larger numbers are involved. On one occasion five females flew into an awaiting net in this manner.

H. affinis and H. gracilipalpis

As mentioned elsewhere (See Chapt. II), the affinis / gracilipalpis complex is considered under the general heading of H. affinis since the author was unable to distinguish between the females of the two species. However, it is believed that of the two, H. affinis is by far the more abundant.

This species first appeared on July 6th in 1947, June 29th in 1948, and not until July 14th in 1949. The numbers increased rapidly until July 20th when it was by far the most abundant species present and continued to be so until H. septentrionalis became dominant.

FIG. 17 SUCCESSION and RELATIVE ABUNDANCE 56



From August 2nd to 20th when affinis and septrionalis were the only species of Hybomitra present as adults, affinis was always the first on the wing, usually appearing between 0800 and 0900 hours and remaining dominant until mid-day, when the activity of septrionalis had so increased that it became dominant.

By August 20th, H. affinis had all but disappeared, the tabanid fauna being represented by only one species, H. septrionalis.

H. affinis is a persistent attacker of man in the north, the bite often being extremely painful and irritating, and, in some individuals, a marked degree of swelling is evident. (Fig. 18).

H. septrionalis

This species was very late in appearing in 1949, the first specimens being taken July 23rd. In previous years it was recorded on July 17th in 1947, and on July 4th in 1948. It had become plentiful by July 29th and was the dominant species by August 2nd. It retained its dominance until August 20th, when observations ceased, and was still very much in evidence on that date.

Although only about one third the weight of affinis, (see Table 1, Page 69) septrionalis is every bit as troublesome and its bite can be just as painful and irritating.



Fig. 18. Abnormal Swelling Resulting from
the Bite of H. affinis

By virtue of its relatively silent approach, the species is able to land unnoticed on an exposed limb or neck. With affinis, septentrionalis forms a pair of blood-sucking flies which can inflict heavy losses on wild animals and can seriously incapacitate human beings. Tales of cattle being stampeded and, in northern latitudes of husky dogs actually being killed by the voraciousness of tabanid attacks, are not without foundation.

During the height of tabanid activity in 1949, the observer was able to watch affinis and septentrionalis attack huskies which were tethered to trees. Up to six flies would be biting at the same time despite frantic pawing and grovelling, and within a very short time the areas above and between the eyes and around the ears were matted with blood. Only when the dogs' master alleviated their sufferings with a copious dose of pine tar and lard could they settle down, although they were still harassed by the persistent buzzing of H. affinis. The most troublesome of the two species as far as biting was concerned was septentrionalis. Throughout the season this species also proved to be the most persistent attacker of man.

Portchinsky (24) has reported for Tabanus montanus, T. maculicornis, and Chrysops spp., the habit of skimming and dipping proboscides in the water. About five times as many males as females were observed in this activity. In 1948 H. septentrionalis was observed in a similar activity, but, in this species, the

females were observed and the activity consisted of a continuous flight about 3-4 inches above the water, with occasional stops, when the flies drop momentarily, or sometimes for an interval of a number of seconds, on to the surface of the water.

The males of this species are probably often overlooked for their flight habits are very similar to those of the Syrphidae and they can easily be mistaken for the latter. They have a curious habit of hovering from a few inches above the ground to a height of approximately 18 feet, making sudden darting motions forward so rapidly that one can scarcely follow their flight. The male of H. septentrionalis is about the same size as the female. Only the lower half of the eye is barred horizontally.

H. itasca - Reared only in the insectary.

Hybomitra sp. (new?) - Reared only in the insectary.

Atylotus ohioensis - Reared only in the insectary.

C. furcata

On July 20th, two specimens of C. furcata were taken. This species was captured on the same date in 1947, and in 1948 on July 4th, considerably earlier.

Although never very plentiful, C. furcata was by far the most abundant species represented in the genus. It remained dominant until August 15th, although it was the only one present on August 20th, when again it was the dominant species.

C. frigida

This northern transcontinental species has always been accepted as unusually variable in size and color (23). It was first taken on July 29th and the last specimen observed was August 5th. Taken on July 13th in 1947 and on July 7th in 1948.

C. nigripes

First taken on July 29th and remained in approximately equal numbers with C. frigida until August 5th. It had established itself as the dominant Chrysops species in the field by August 15th. No specimens were captured or seen after this date. This species was taken on July 13th in 1947 and on the same date in 1948.

C. carbonaria

In 1947 this species was first taken on July 12th and remained present in the fauna until August 12th when observations ceased that year. It was the most abundant species up until near the end of July. In 1948 it was taken on July 7th and had been recorded intermittently throughout the season's observations. However, in 1949 only one specimen was captured and this one on July 29th. (not recorded in Fig. 17).

Species of Chrysops were so few in number during the 1949 season that their presence could scarcely be considered as annoying. No members of the group were bitten although investigators in 1948 received bites.

3. 2. PLANTS FED UPON

Relatively little is known of this subject owing to the difficulties encountered while endeavoring to make observations. The Tabanidae, as a group, are very restless and furtive so that if an investigator is fortunate enough to observe a specimen on a plant it is extremely unlikely that he will be able to ascertain whether the insect is feeding or merely resting, before his presence has resulted in a hasty flight.

A number of specimens of H. affinis and H. septentrionalis was captured early in the season, all literally covered with pollen. These could easily have been mistaken for different species for their bodies were yellow-white in color. The pollen grains, mounted in euparal, were identified by Miss L. Kennedy, Department of Botany, University of Alberta, as Salix sp. and Ledum sp. respectively.

There is no doubt that the tabanids do feed on nectar and probably in this area the vast majority taste nothing else in their lifetime. Many specimens of both H. affinis and H. septentrionalis were captured and found to be completely engorged. On dissection it was found that the entire abdomens were filled to capacity with a clear viscous fluid. When rubbed between the fingers this fluid was sticky and it was also sweet to the taste, suggesting nectar. A positive test for reducing sugars was obtained with Benedict's solution. When a recently fed insect is dissected, the nectar is found to be confined into

a small clear blob by the delicate peritrophic membrane. Many of these blobs were taken from the abdomens of engorged females and placed on a piece of paper. Other females were immediately attracted to them and, piercing the membrane with their mouthparts, soon had the nectar sucked up.

3. 3. MATING

Mating was not observed in any of the tabanid species in 1949 but three occurrences were recorded in 1948. The pairs were in copula during flight and lucky sweeps of the net resulted in the capture of two of the pairs, both being H. gracilipalpis. The other pair, believed to be H. affinis, was observed on July 11th. Mating took place on the wing over water in open woods. The individuals remained connected for some 5 seconds while flying from low over the water to a considerable height. They then separated and flew off individually.

3. 4. BLOOD MEALS

Some time elapses after emergence before the female exhibits any tendency to take a blood meal from man. H. affinis, which was first observed in the field on July 14th, did not bite until July 24th, although 8 days of adult activity were recorded between these dates. Similarly H. septentrionalis, which was first observed in the field on July 23rd, did not bite until July 30th. Five days of adult activity were recorded

between these dates. Possibly the period would be somewhat lessened if weather conditions were consistently favorable. Food during this interval appears to be obtained from flowers or wild animals.

When in captivity, little inclination to feed is shown. A moist forearm inserted into a cage containing captured females, goes completely unnoticed. However they would consume a droplet of water placed on the floor of the cage.

The effects of a tabanid bite vary with individuals. Some members of the group were not bitten at all, while other members were continually 'tapped' for blood meals. Biting would cause noticeable swelling and irritation in one person while little or no effect would be experienced by another. Generally speaking, it was found by this observer that during the time the mouthparts were inserted, quite an acute pain was felt but no after-effects were experienced until 48 hours later when intense irritation started which lasted for 2 or 3 days. In most instances a droplet of blood was left over the punctured area. The common observation that considerably less irritation is experienced if a tabanid is allowed to finish a blood meal is not supported by personal experience. In every case, the irritation has been far more excessive when the fly was allowed to complete its blood meal than when it was

swatted away as soon as the sting was felt. The effects of bites of H. affinis on three different individuals are cited below:

1. A bite was received on the palm-side of the third finger of the right hand between the first and second joints. A slight pain was experienced as the mouthparts were inserted and 30 seconds later a much more intense pain. Mouthparts were inserted for 3 minutes and 50 seconds, and when withdrawn, a large drop of blood was left over the area. Within 5 minutes of receiving the bite the finger was noticeably swollen. One half hour later, the swelling had spread and was obvious around the second and third joints on the back of the finger. An hour later, the entire hand up to the wrist had swollen to one half again its normal size. At this time the hand became very itchy.

The following morning the swelling had spread up to the elbow and the whole arm had become abnormally large (Fig. 18). Soreness was reported around the knuckle joints and irritation along the entire length of the forearm. The individual sought medical attention the same morning and within two days' time the arm and hand were back to normal.

No other individuals who were bitten throughout the season suffered such discomfort and swelling as this. It may be significant to note that the blood of the man in question belongs in the "A" group.

2. This investigator was pierced twice by the same female (this is often the case, occasionally three or four insertions are made before the blood meal is completed). Sharp pain was felt as soon as the mouthparts were inserted but thereafter no discomfort in the form of swelling or itching was experienced. There was no noticeable marking on the skin until an hour after the bite was received and then a small red wheal appeared surrounded by an area of blueness. These effects persisted for 3 days and disappeared. This bite was received on the inside of the forearm of an individual whose blood grouping is "O".

3. A female H. affinis was captured inside a small shed (Fig. 16) and placed on the leg approximately 6 inches below the knee of the third observer. Within a minute the fly had made its first of two insertions. Prior to puncturing the skin, the female had gone through a ritual of feeling the skin with the fore-tarsi and tip of the proboscis. The tarsi were rubbed together, beginning at the fifth segment, then along the inside, to the bases of the tibiae. This procedure was repeated five or six times and gave the observer the odd impression of a hungry man rubbing his hands together in anticipation of indulging in a well-prepared meal. During the procedure the forelegs were often raised over the head and the inside of the tibiae brought forward and down over the eyes and continuing down, rubbing the antennae.

The mouth parts were inserted for only 20 seconds in the first area, then removed and inserted into the second area for 3 minutes and 48 seconds, where the entire meal was taken. A sharp pain was felt as soon as the mouth parts were inserted, followed by a very acute pain, sufficient to cause wincing, between 25 and 40 seconds later. This acute pain lasted for 15 to 20 seconds after which time there was no further discomfort felt as the adult completed her meal. No visible mark was left on the skin from this bite but a drop of blood remained over the area.

Twenty-four hours later, a red wheal approximately one inch in diameter had appeared and the whole area had become extremely itchy. The wheal increased in diameter to approximately 2 inches and itchiness continued off and on for a period of a week. No swelling occurred.

The observer, whose blood grouping is "O", received many bites throughout the season, and in all cases the results were almost the same as described above, with slight variations in time. There was little difference experienced between the bites of H. affinis and H. septentrionalis.

When viewed with the aid of a hand lens, a biting tabanid presents a forbidding sight. The labella is spread to such an extent that the bottom of the head is almost touching the skin. On either side of the labella the palpi keep tapping, and on either side of the palpi the forelegs are braced, all

the tarsal segments resting on the skin. With each contraction of the powerful pharyngeal muscles the entire abdomen heaves and distends.

The connective membrane between the abdominal tergites and sternites is not visible in a non-engorged female, but once the fly has become completely engorged, this membrane is clearly visible and stretched almost to the apparent point of bursting. When fully engorged, the abdomen is so heavy that it touches the surface over which the fly is walking, and if the female is thrown into the air, forward flight is impossible, so awkward and weighty has she become. This statement applies to both H. affinis and H. septentrionalis

Once the mouthparts have been inserted and partaking of the blood meal begun, one may walk around, gently wave the arms, place an empty bottle over the female, but unless something of more violent nature is done, the fly will not release her hold. More time appears to be required if the blood meal is sought, for example, over the shin, than if the meal is sought from a more fleshy part of the body, e.g. the neck.

It will be seen from an examination of Table 1 that ^{at} H. affinis is able to more than double its original weight by engorging completely, while H. septentrionalis is able to consume only slightly less than one half her own body weight. Cattle subjected to the attacks of H. affinis for a period of

TABLE 1 - Weights of tabanid blood meals and times taken to complete engorgement.

SPECIES	Weight of fly	Weight of blood meal	TIME	
			Mins.	Secs.
<u>H. affinis</u>	0.1638	0.1710	3	- 45
	0.1353	0.1347	3	- 48
	0.1407	0.1593	9	- 3 *
	0.1407	0.1585	4	- 2
			1	- 50 **
Average	0.1451	0.1559	4	- 30
<hr/>				
<u>H. septentrionalis</u>	0.0519	0.0280	4	- 20
	0.0647	0.0264	9	- 8 *
Average	0.583	0.0272	6	- 44

* Three separate punctures were required before the flies were completely engorged. Times were recorded from the moment the sting of the mouthparts was felt until they were finally withdrawn.

** Bite received on the fleshy part of the neck below the lower jaw.

10 hours would lose approximately 75 milliliters of blood if bites were received at the rate of 50 per hour. (Specific gravity of cow's blood is approximately 1.055). Similarly cattle stand to lose approximately 13 milliliters of blood from the attacks of H. septentrionalis under the same circumstances.

These last data do not agree with those obtained by Cameron (5) for H. septentrionalis, who found that each specimen could engorge approximately 0.2 cc. of blood, nearly ten times the amount recorded in our observations. In point of fact, our observations show that H. affinis, which is a considerably larger species than H. septentrionalis, engorges only 0.15 millilitres, some 0.05 millilitres less than Cameron's observations for septentrionalis

3. 5. EGGS

Search for the egg masses of Tabanidae was conducted throughout the adult season and during the latter part of August, to the exclusion of other activities, no egg masses were found although vegetation surrounding known larval habitats was searched thoroughly. The following possible explanations are reservedly put forward:

1. That only the ovaries of those females which have partaken of a blood meal become fully developed and produce a full complement of viable eggs. If this statement were true, egg masses would be extremely rare owing to the fact that in all

probability only a very small fraction of the female population ever receive a blood meal. The chances of locating the masses would be correspondingly remote.

2. That only a small fraction of the eggs present in females that feed exclusively on nectar are laid. On days when adults were on the wing, females were dissected to note the condition of the developing eggs. One would expect to find a gradual change to fully developed eggs as the season progressed but this was not so. Dissections of one specimen of H. septentrionalis revealed two large cigar-shaped eggs with developed chorion whilst the remaining eggs were still very undeveloped in the ovaries. It is possible that under such conditions, the eggs would be laid singly, or in pairs.

Specimens of H. affinis which had received a blood meal and caged for possible oviposition, were later dissected. There was a remarkable difference in the development of the eggs of these specimens and those of the specimens captured in the field on the same day. The eggs of the blood-fed females were cigar-shaped and all about equal in size to one another, while those of the field-captured females were still very undeveloped with the exception, in one instance, of one large completely developed egg.

3. Since investigators in 1947, 1948, and 1949 have failed to locate the egg masses, one might assume that the masses of these northern species are not laid on pond vegetation, etc.,

where those of other species are normally found. The eggs could be deposited in, or on the moss, where the hatched larvae would be in a damp environment. Eggs laid singly in moss, of course, would be next to impossible to find.

Egg counts from dissected females are recorded in Table 2.

3. 6. CORRELATION OF ADULT ACTIVITY WITH WEATHER

Adverse weather conditions prevailed throughout these observations. Adult activity was recorded on only 23 out of 46 days, and on many of these days, ceased after 1 or 2 hours.

The graphs in Figs. 19 and 20 were drawn from data recorded on 4 days -- July 31st, August 2nd, August 15th, and August 20th. To obtain comparative numbers of adults on the wing throughout the day, the door of a dark-green shed (Fig. 16) was left open for 15 minutes out of every hour. The flies swarmed around the shed and many of them entered the open door and congregated on the windows inside. During the 15 minutes that the door was open, temperature, light, and wet and dry - bulb thermometer readings were taken. The next 45 minutes were spent inside the shed catching the flies with a killing bottle and recording the species.

It will be seen from a study of the graphs that maximum activity was recorded when the temperature was between

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TABLE 2 - Egg counts from the ovaries
of dissected female tabanids.

SPECIES	EGG COUNTS	AVERAGE
<u>H. affinis</u>	793,816,818,840	817
<u>H. gracilipalpis</u>	445,492,498,564	500 *
<u>H. septentrionalis</u>	326,372,472	390
<u>H. metabola</u>	332,338	335
<u>C. furcata</u>	257,364,222	281

* Specimens which appeared too small to be females of H. affinis were used in making this count. As will be observed, the ovaries differed in mean egg count from those of H. affinis by some 320.

FIG. 19 VARIOUS FACTORS INFLUENCING
ADULT ACTIVITY

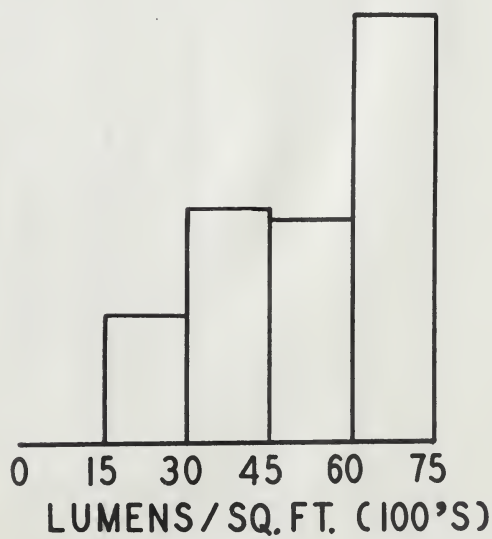
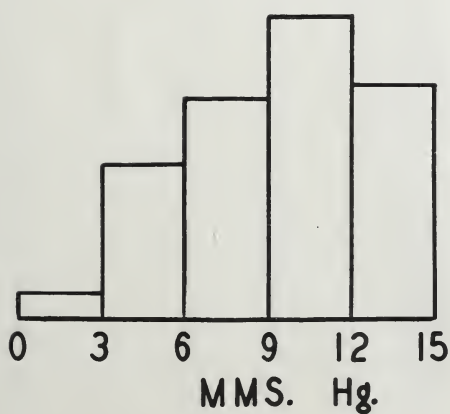
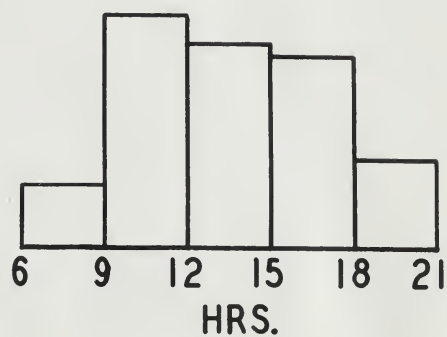
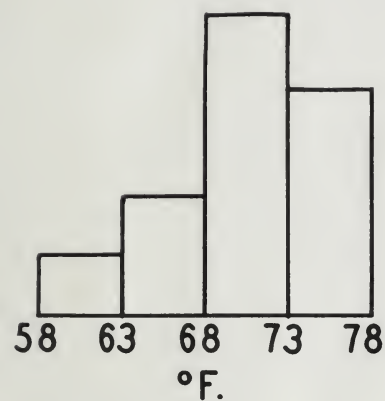
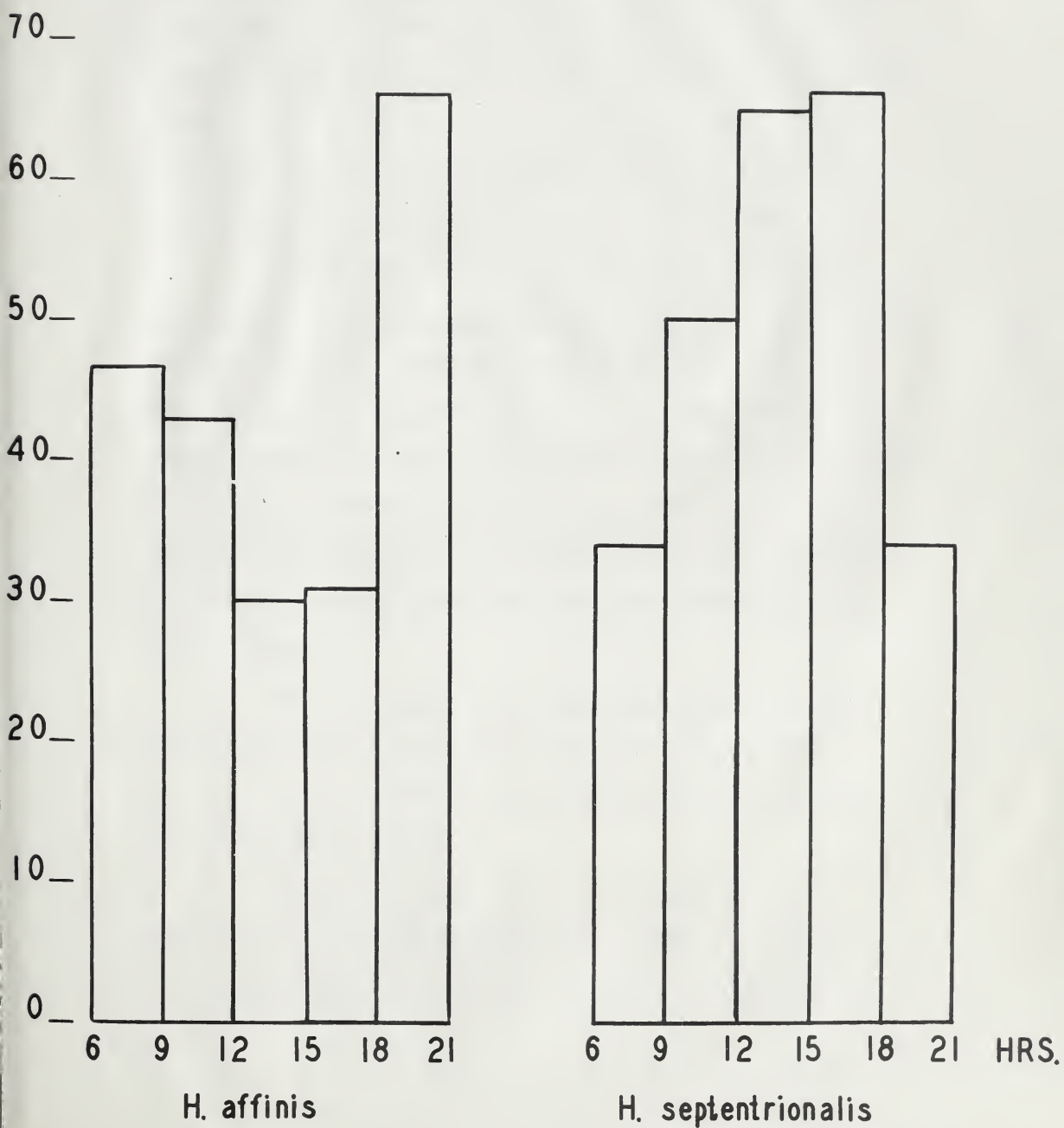


FIG. 20 COMPARATIVE ADULT ACTIVITY



68°F and 73°F, the saturation deficiency was between 9 and 12 mms. of Hg., and light was between 6000 and 7500 lumens/sq. ft.. However, this last figure represents only one observation. More adults were active between 0900 hours and 1200 hours, the largest numbers being recorded between 1000 hours and 1200 hours. From midday on, there is a gradual decline in numbers until 1800 hours when the numbers begin to decline. After 1800 hours temperature and light readings fall off rapidly.

Graphs (Fig. 20) comparing the adult activity of H. affinis with H. septentrionalis show that the former is an early morning-late afternoon species, while the latter is a late morning-early afternoon species. The total numbers remain fairly constant from 0900 hours to 1800 hours but the composition of the species varies from hour to hour. Similar graphs were obtained when the numbers of H. affinis and H. septentrionalis were plotted against temperature, saturation deficiency, and light intensity.

While H. affinis and H. septentrionalis dominated the tabanid fauna throughout the day, other species were present in varying numbers. The percentage of these species present is given in Table 3.

Fraenkel and Gunn (7) do not speak of 'tropisms' leaving the word to the botanists who restrict its meaning to the turning reactions of plants. The modern term 'taxis' is

TABLE 3 - Minor tabanid species present during the dominance of H. affinis and H. septentrionalis. Percentage of total population at various times of day.

SPECIES	6-9	9-12	12-15	15-18	18-21 Hrs.
<u>H. metabola</u>	0	0	0.75	0.3	0
<u>C. furcata</u>	6	4	2.25	1.5	0
<u>C. nigripes</u>	13	1	1.5	1.2	0
<u>C. frigida</u>	0	2	.75	.3	0

used for directed orientation reactions. Thus positive and negative photo-taxis mean respectively movement straight towards or straight away from the light. Similarly, the terms photopositive and photonegative would mean assembly in light or dark areas respectively, regardless of the mechanism by which this was brought about. This more recent terminology is adopted here.

It is common knowledge that tabanids are lovers of sunlight and they are 'attracted' to moving or stationary vehicles. Any one who has gone swimming in a pool or stream in the vicinity of horseflies or deerflies knows that their attacks are far more persistent when the body is wet. We run into difficulties however, when we attempt to explain these phenomena.

No satisfactory answer can yet be given why tabanids collect around darkened objects to such an extent that hundreds of specimens can be captured in a few minutes. Since the response is toward an area of reduced illumination, it is therefore photonegative. On the other hand, once inside an area of low intensity, a shed for instance, the tabanids congregate on the windows in an apparent attempt to escape. This response is toward an area of high intensity and is therefore photopositive. So here we have evidence of an insect being photonegative in high illumination and photopositive in low illumination.

Due to heat radiated from a darkened object, it seems probable that the temperature surrounding the object would be slightly higher than it would be some distance away. If the former temperature was nearer the temperature for optimum activity for the particular species, the numbers of the species in the immediate vicinity would congregate in the higher temperature surrounding the object. But this does not explain tabanids coming considerable distances toward the stimulus. Heat would be radiated for a matter of only a few feet away from the object.

However it would appear that the combination of temperature and light are important factors for the flies are seldom seen in any numbers on the shady-side of a building where the temperature and light is reduced. Nevertheless, a few flies do collect on the shady side.

A possible explanation for the flight toward a darkened object may lie in the fact that the object does not conform in shape with the tabanids normal environment and this difference in shape may excite the 'curiosity' of the insect to such an extent as to stimulate locomotary activity towards the object.

3. 7. FIELD EMERGENCES

In order to obtain information on adult populations, sex ratios, and to obtain the males of tabanid species, ten frames, each measuring 6 feet in length, 3 feet in width, and

3 feet in height were constructed of 2 in. by 2 in. lumber. Each frame was then covered with cheesecloth along the sides, ends and on the top. The bottom 6 inches of each corner peg was sharpened to a point to facilitate anchoring the cage into the ground.

In one corner of each cage a small opening was left about 18" by 12" which was covered with a lid. When collecting the flies, the lid was removed and replaced by a smaller cage, which just fitted into the corner opening. Selected sites were chosen representing various known larva^l habitats and the cages then driven into these areas. Small furrows, slightly more than 2 inches wide and 6 inches deep were dug along the length and width of the bottom to enable the cage to be well sunk so that adults could not escape through the bottom. Once in place, the possibility of adults escaping was further minimized by banking the sides and ends with moss.

Advantage was taken of the photopositive reactions of the adult flies to effect their capture once they had emerged into the large cages. At first, five large, dark army blankets were draped over the entire cage so as to completely darken the interior. A hole was cut in one of the blankets to allow the smaller cage to fit into position. Once the large cage was darkened and the smaller cage, constructed of transparent plastic, was in position, it was

only a matter of 5 to 10 minutes before all flies had become concentrated within the smaller, light cage. Capture was completed by sliding a piece of plastic into grooves along the bottom of the smaller cage. The emergence of the flies into the smaller cage was hastened by gently tapping the sides, ends, and top of the larger cage with an insect net, (Fig. 23). Once inside, the insects were chloroformed, returned to the laboratory, pinned and labelled.

The use of army blankets to drape over the cages was found to be impractical because they were very bulky, and allowed a certain amount of light through. To obviate these difficulties a one-piece canopy of black, water-proof canvas was later made.

Five areas where larvae were found during the early days of June were chosen in which to place the cages. The vegetative ground cover for each area, as described by Mr. Peter Hyde, Defense Research Board, on August 2nd is given below.

Area 1. Point 904065, Fig. 21.

A flat, somewhat marshy area with numerous small mossy hummocks and saturated depressions. Larix laricina (Du Roi) Koch (tamarack) and Betula glandulosa Michx. (Betulaceae) (glandular birch), were the common trees in the immediate vicinity.

List of flora:

Salicaceae - Salix reticulata L.

Lentibulariaceae - Pinguicula vulgaris L. This is
the carnivorous butterwort.

Scrophulariaceae - 1. Bartsia alpina L. (Alpine Bartsia)

2. Pedicularis lapponica L.
(Lapland lousewort)

Ericaceae - 1. Vaccinium uliginosum L. (bog bilberry)

2. Ledum spp.

Cyperaceae - (sedges) Several genera.

Juncaginaceae - Triglochin palustre (arrow-grass)

Rosaceae - Dryas integrifolia Vahl. (Arctic avens)

Orchidaceae - Spiranthes Romanzoffiana Cham. & Schlecht
(hooded ladies' tresses)

Equisetaceae - Equisetum variegatum (variegated horsetail)

Area 2. Point 904066, Fig. 22.

An open, marshy area covered with small hummocks and reindeer moss, Cladonia rangiferina L. Web.. Shelter trees were white spruce, Picea glauca (Moensch) Voss, tamarack, and procumbent birch.

Arrow grass was very common. Less common were arctic avens, bog bilberry, trailing azalea, Loiseleuria procumbens L. Desv. and mountain cranberry Vaccinium Vitis - Idaea L. var. minus Lodd.

The ground surface was mainly peat covered with hypnaceous mosses.



Fig. 21. No. 1 Field Cage Area

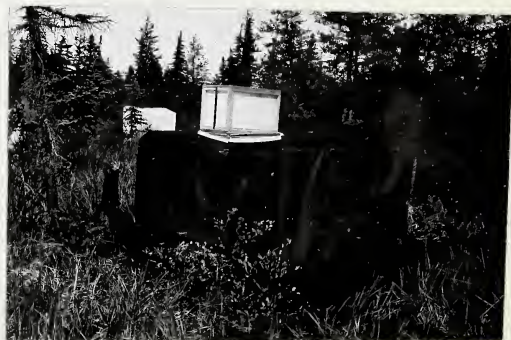


Fig. 22. No. 2 Field Cage Area

Area 3. Point 904069, Fig. 23.

An irregularly shaped marsh of approximately one acre sheltered by white spruce and tamarack rising to a height of 30 feet. Occasional low, wet hummocks were interspersed throughout this area. Sedges and rushes were common. Bladderworts, hooded ladies tresses, dwarfed glandular birch and Labrador tea were also represented in the flora.

Area 4. Point 924025, Fig. 24.

This area was much wetter than the previous areas. Shelter was afforded by black spruce, Picea mariana Mill. B.S.P. and tamarack which was growing to a height of 10 feet. Plants in evidence were Labrador tea, bog bilberry in drier situations, arrow grass, and Carex spp.

Area 5. Point 926027, Fig. 25.

A boggy marsh sheltered by white spruce and tamarack. The vegetative cover was less luxuriant than in the previous areas but included similar vegetation.

Ten cages were distributed among the areas 1 to 5 as follows: 2, 3, 3, 1, 1. These were examined and cleared daily.

Tabanid species which emerged were identified as H. septentrionalis, H. affinis, Hybomitra sp., C. nigripes, C. frigida and C. furcata. The first and last dates of emergence and the numbers and sex are given in Table 4.

Twenty adults emerged into the 10 cages and since each cage covered an area of 2 square yards, this represents an



Fig. 23. No. 3 Field Cage Area



Fig. 24. No. 4 Field Cage Area



Fig. 25. No. 5 Field Cage Area.

TABLE 4 - Emergence periods and sex of
tabanids obtained from field cages.

SPECIES	DATE		NOS. AND SEX	
	1st Emergence	Last Emergence	Male	Female
<u>H. septentrionalis</u>	24.VII	8.VIII	3	1
<u>H. affinis</u>	28.VII	8.VIII	1	1
<u>Hybomitra</u> sp.	30.VII	30.VII	1	-
<u>C. nigripes</u>	23.VII	30.VII	2	1
<u>C. frigida</u>	15.VII	30.VII	2	4
<u>C. furcata</u>	20.VII	30.VII	-	4
TOTAL			9	11

emergence of 4840 tabanids per acre, or approximately 3 millions per square mile, of apparently suitable larval habitat. There were 2 cages in which no adults emerged. This figure is rather on the conservative side for the following reasons:

1. It is believed that adults did escape through the bottoms of the cages. As the season progressed, the moss which was used to bank the sides and ends became very dry, and on particularly windy days, much of this moss was blown away leaving possible exits for the flies. To obviate this difficulty, cages constructed for future work of this nature should have the bottom 6 inches along the sides and ends enclosed with a metal or wood strip. This portion of the cage would be submerged and banking would not be necessary.

2. The escape of adults could also have been possible through holes in the cheesecloth caused by snagging and rotting. An added disadvantage of the use of cheesecloth is that tipulids get tangled easily which makes their collection difficult.

3. The northland muskeg abounds with predatory spiders of all descriptions and sizes. On numerous occasions they were present inside the cages and had woven webs in the corners. The actual feeding of a spider on a tabanid adult inside a cage was not witnessed, but on two separate occasions the observer watched spiders attack, and devour large anthomyids.

It is quite possible too, that the very common lemming, Dicrostonyx groenlandicus (Merriam), could destroy numbers of adults as the latter shelter in the moss. In captivity, lemmings will devour up to 20 proffered tabanids.

The numbers of the various species emerging into the cages were too small to arrive at a sex ratio.

For further work along these lines it is suggested that fewer but larger cages be used. The number of enclosed areas would largely depend on the number of men available but the area enclosed by each cage should not be less than 10 square yards. A different method of collecting the emergences would have to be devised but this should present no insurmountable difficulty. A light trap might be utilized or perhaps catwalks inside the cage would provide the answer. Of course, not only emergences of tabanids but all emergences should be kept to obtain associations. To ensure that small insects did not escape, it is suggested that a 26-mesh wire or plastic screening be used instead of cheesecloth.

Other dipterous and hymenopterous emergences are recorded in Tables 5, 6 and 7.

TABLE 5 - Emergences of other orthorrhaphous flies in field cages.

FAMILY - GENUS	No.	Approximate Numbers / Acre
Tipulidae	-	-
Psychodidae	3	750
Sciaridae	7	1750
Chironomidae	-	-
Stratiomyidae	10	2500
Empidae		
<u>Rhamphomyia</u> Meigen	12	3000
<u>Drapetis</u> Meigen	2	500
<u>Coloboneura</u> Mldr.	1	250
Dolichopidae		
<u>Dolichopus</u> Latreille	3	750

TABLE 6 - Emergences of cyclorrhaphous flies
in field cages.

FAMILY - GENUS	No.	Approximate Numbers / Acre
Phoridae	3	750
Syrphidae		
<u>Melanostoma</u> Big	5	1250
<u>Lejops</u> Willis	1	250
Chloropidae	3	750
Agromyzidae	3	750
Trypetidae	1	250
Borboridae	4	1000
Tetanoceridae		
<u>Tetanocera</u> Dumeril	7	1750
<u>Dictya</u> Meigen	2	500
Cordyluridae	25	6250
Anthomyidae	35	8750
Sarcophagidae	1	250
Calliphoridae	1	250

TABLE 7 - Emergences of Hymenoptera in
field cages.

	No.	Approximate Numbers / Acre
Tenthredinidae	3	750
Chalcidoidea	1	250
Ichneumonidae	7	1750
Braconidae	2	500

Insectary Rearing

One of the main objects during the 1949 season was to rear larvae in the insectary and to associate the emerged adults with their last larval exuviae and pupal skins. Insectary rearings would also determine the length of life cycle.

1. METHOD EMPLOYED

The technique evolved was the result of trial and error coupled with the knowledge of successes recorded by other students of tabanids. Larvae collected in the field were brought to the insectary and placed in individual containers.

One of the main difficulties experienced was that of the larvae escaping through the cheesecloth covers. Although the cheesecloth was folded several times, it was still possible for the smaller larvae to worm their way through the mesh and escape. The larvae are active during the night, remaining embedded in the moss during the day. On numerous occasions larvae were found dead in the morning, having become entangled in the mesh during the night. In order to obviate this difficulty, small squares of ply wood were cut and placed over the mouths of the containers, but larvae still escaped. Frequently winds during the night would shake the walls and shelves of the metal insectary (Fig. 26) sufficiently to



Fig. 26. Interior of Metal Insectary

dislodge these wooden tops. Finally, 4 oz. and 8 oz. specimen jars with metal screw tops solved this problem; having no neck constriction it was relatively easy to remove the moss for examination. Sealers were too large and occupied too much space. Larvae did not have sufficient room for activity when reared in 60 cc. test tubes. Three hundred larvae were reared and each larva was given a number. Date collected, size, color, etc., were recorded for each larva, and as the season progressed, changes in appearance, the date of pupation, and any other relevant information was noted. These data are recorded in Table 8. When pupation occurred, the moss was searched for the last larval excuvium, which was preserved in an alcohol-glycerin mixture in a small shell-vial. When the adult emerged, the pupal skin was transferred to the same shell-vial and was identified by labelling with the number of the original larva.

2. MORTALITY

When a larva died, it was preserved and replaced by a healthy specimen so that throughout the rearing experiment 300 larvae were constantly under observation. Larval mortality was attributed to four causes:

i. Natural mortality

ii. Mortality resulting from rough handling. Usually the larva was easily seen in the specimen jar but occasionally it became embedded in a small clod of moss and was extremely

Table 8. Data on insectary rearing of tabanid adults (comments are those of Mr. G.E. Shewell, who kindly determined the specimens).

Species	Numbers		Larval Length (MMS)		Pupations		Average Pupal Period (days)	Range of Pupal Period	Pupal Length (MMS)		Emergence
	Male	Fe-male	Av.	Range	Date	Range			Av.	Range	
<u>H. septentrionalis</u>	15 ^a		17.5	8-22	30.VI-9.VII		23.5	18-28	16	15-17	23.VII-2.VIII
<u>H. septentrionalis</u>		12 ^b	20	17-23	2.VII-9.VII		22.5	19-26	16.5	15-17	23.VII-2.VIII
<u>H. gracilipalpis</u>		1	20		2.VII		23		19		25.VII
<u>H. affinis</u>	1		24		30.VI		24		20		23.VII
<u>H. itasca</u>	1 ^c		18		6.VII		25		16		31.VII
<u>H. itasca</u>		2	15.5	12-19	7.VII-9.VII		27		17.5	17-18	3.VIII-5.VIII
<u>Hybomitra</u> sp(new?)		1	16		9.VII		28		15		6.VIII
<u>Hybomitra</u> sp	1 ^d		21		2.VIII		23		17		25.VIII
<u>A. ohionensis</u>	1 ^e		15		2.VII		28		15		30.VII
<u>A. ohionensis</u>		1 ^e	14		9.VII		25		14		3.VIII
<u>C. nigripes</u>		12	11	6-17	28.VI-8.VII	15-20	17		10	9-14	15.VII-29.VII
<u>C. nigripes</u>	19		11	10-13	28.VI-16.VII	16-20	17.5		10.5	8-12	15.VII-1.VIII
<u>C. frigida</u>		8	10	9-11	2.VII-22.VII	17-21	18.5		10	9-11	20.VII-9.VIII
<u>C. frigida</u>	4		11	9-13	29.VI-8.VII	16-20	18		10	9-11	15.VII-28.VII
<u>C. furcata</u>	1		10		4.VII		18		12		22.VII

a - 3 determinations doubtful.

b - 2 determinations doubtful. Data of one specimen which

c - pupated 2.VII and emerged 23.VIII are not included.

d - doubtful determination.

e - perhaps the male of H. itasca.

e - much darker than the usual form.

1. *Chrysomelidae* (beetles)
 2. *Curculionidae* (weevils)
 3. *Chrysomelidae* (beetles)
 4. *Curculionidae* (weevils)
 5. *Chrysomelidae* (beetles)
 6. *Curculionidae* (weevils)
 7. *Chrysomelidae* (beetles)
 8. *Curculionidae* (weevils)
 9. *Chrysomelidae* (beetles)
 10. *Curculionidae* (weevils)

No.	Date	No. of plants		No. of insects	No. of eggs	No. of larvae	No. of pupae	No. of adults	Remarks
		Infested	Healthy						
1	1910. 1. 1	1	1	1	1	1	1	1	1
2	1910. 1. 1	1	1	1	1	1	1	1	1
3	1910. 1. 1	1	1	1	1	1	1	1	1
4	1910. 1. 1	1	1	1	1	1	1	1	1
5	1910. 1. 1	1	1	1	1	1	1	1	1
6	1910. 1. 1	1	1	1	1	1	1	1	1
7	1910. 1. 1	1	1	1	1	1	1	1	1
8	1910. 1. 1	1	1	1	1	1	1	1	1
9	1910. 1. 1	1	1	1	1	1	1	1	1
10	1910. 1. 1	1	1	1	1	1	1	1	1
11	1910. 1. 1	1	1	1	1	1	1	1	1
12	1910. 1. 1	1	1	1	1	1	1	1	1
13	1910. 1. 1	1	1	1	1	1	1	1	1
14	1910. 1. 1	1	1	1	1	1	1	1	1
15	1910. 1. 1	1	1	1	1	1	1	1	1
16	1910. 1. 1	1	1	1	1	1	1	1	1
17	1910. 1. 1	1	1	1	1	1	1	1	1
18	1910. 1. 1	1	1	1	1	1	1	1	1
19	1910. 1. 1	1	1	1	1	1	1	1	1
20	1910. 1. 1	1	1	1	1	1	1	1	1
21	1910. 1. 1	1	1	1	1	1	1	1	1
22	1910. 1. 1	1	1	1	1	1	1	1	1
23	1910. 1. 1	1	1	1	1	1	1	1	1
24	1910. 1. 1	1	1	1	1	1	1	1	1
25	1910. 1. 1	1	1	1	1	1	1	1	1
26	1910. 1. 1	1	1	1	1	1	1	1	1
27	1910. 1. 1	1	1	1	1	1	1	1	1
28	1910. 1. 1	1	1	1	1	1	1	1	1
29	1910. 1. 1	1	1	1	1	1	1	1	1
30	1910. 1. 1	1	1	1	1	1	1	1	1
31	1910. 1. 1	1	1	1	1	1	1	1	1
32	1910. 1. 1	1	1	1	1	1	1	1	1
33	1910. 1. 1	1	1	1	1	1	1	1	1
34	1910. 1. 1	1	1	1	1	1	1	1	1
35	1910. 1. 1	1	1	1	1	1	1	1	1
36	1910. 1. 1	1	1	1	1	1	1	1	1
37	1910. 1. 1	1	1	1	1	1	1	1	1
38	1910. 1. 1	1	1	1	1	1	1	1	1
39	1910. 1. 1	1	1	1	1	1	1	1	1
40	1910. 1. 1	1	1	1	1	1	1	1	1
41	1910. 1. 1	1	1	1	1	1	1	1	1
42	1910. 1. 1	1	1	1	1	1	1	1	1
43	1910. 1. 1	1	1	1	1	1	1	1	1
44	1910. 1. 1	1	1	1	1	1	1	1	1
45	1910. 1. 1	1	1	1	1	1	1	1	1
46	1910. 1. 1	1	1	1	1	1	1	1	1
47	1910. 1. 1	1	1	1	1	1	1	1	1
48	1910. 1. 1	1	1	1	1	1	1	1	1
49	1910. 1. 1	1	1	1	1	1	1	1	1
50	1910. 1. 1	1	1	1	1	1	1	1	1
51	1910. 1. 1	1	1	1	1	1	1	1	1
52	1910. 1. 1	1	1	1	1	1	1	1	1
53	1910. 1. 1	1	1	1	1	1	1	1	1
54	1910. 1. 1	1	1	1	1	1	1	1	1
55	1910. 1. 1	1	1	1	1	1	1	1	1
56	1910. 1. 1	1	1	1	1	1	1	1	1
57	1910. 1. 1	1	1	1	1	1	1	1	1
58	1910. 1. 1	1	1	1	1	1	1	1	1
59	1910. 1. 1	1	1	1	1	1	1	1	1
60	1910. 1. 1	1	1	1	1	1	1	1	1
61	1910. 1. 1	1	1	1	1	1	1	1	1
62	1910. 1. 1	1	1	1	1	1	1	1	1
63	1910. 1. 1	1	1	1	1	1	1	1	1
64	1910. 1. 1	1	1	1	1	1	1	1	1
65	1910. 1. 1	1	1	1	1	1	1	1	1
66	1910. 1. 1	1	1	1	1	1	1	1	1
67	1910. 1. 1	1	1	1	1	1	1	1	1
68	1910. 1. 1	1	1	1	1	1	1	1	1
69	1910. 1. 1	1	1	1	1	1	1	1	1
70	1910. 1. 1	1	1	1	1	1	1	1	1
71	1910. 1. 1	1	1	1	1	1	1	1	1
72	1910. 1. 1	1	1	1	1	1	1	1	1
73	1910. 1. 1	1	1	1	1	1	1	1	1
74	1910. 1. 1	1	1	1	1	1	1	1	1
75	1910. 1. 1	1	1	1	1	1	1	1	1
76	1910. 1. 1	1	1	1	1	1	1	1	1
77	1910. 1. 1	1	1	1	1	1	1	1	1
78	1910. 1. 1	1	1	1	1	1	1	1	1
79	1910. 1. 1	1	1	1	1	1	1	1	1
80	1910. 1. 1	1	1	1	1	1	1	1	1
81	1910. 1. 1	1	1	1	1	1	1	1	1
82	1910. 1. 1	1	1	1	1	1	1	1	1
83	1910. 1. 1	1	1	1	1	1	1	1	1
84	1910. 1. 1	1	1	1	1	1	1	1	1
85	1910. 1. 1	1	1	1	1	1	1	1	1
86	1910. 1. 1	1	1	1	1	1	1	1	1
87	1910. 1. 1	1	1	1	1	1	1	1	1
88	1910. 1. 1	1	1	1	1	1	1	1	1
89	1910. 1. 1	1	1	1	1	1	1	1	1
90	1910. 1. 1	1	1	1	1	1	1	1	1
91	1910. 1. 1	1	1	1	1	1	1	1	1
92	1910. 1. 1	1	1	1	1	1	1	1	1
93	1910. 1. 1	1	1	1	1	1	1	1	1
94	1910. 1. 1	1	1	1	1	1	1	1	1
95	1910. 1. 1	1	1	1	1	1	1	1	1
96	1910. 1. 1	1	1	1	1	1	1	1	1
97	1910. 1. 1	1	1	1	1	1	1	1	1
98	1910. 1. 1	1	1	1	1	1	1	1	1
99	1910. 1. 1	1	1	1	1	1	1	1	1
100	1910. 1. 1	1	1	1	1	1	1	1	1

difficult to find. On such an occasion the larva was easily injured.

iii. Predation - High mortality occurred when rearings were first begun owing to the practice of feeding a species of crane-fly larvae to all tabanid larvae. Whilst these proved to be an ideal food for the voracious larvae of Hybomitra spp., they themselves preyed on the larvae of Chrysops spp.. Ten of the latter were segregated in individual rearing jars and 10 tipulid larvae were added, one to each jar. Within a matter of minutes the tipulid larvae attacked their prey and soon had them incapacitated. Twenty-four hours later, 7 of the tabanid larvae had been entirely devoured and the remaining 3 were so badly mutilated as to be unrecognizable. All the tipulid larvae had noticeably increased in size.

Adult specimens of this tipulid species were sent to Dr. C. P. Alexander (1), Massachusetts Agricultural College, Amherst, who identified them as Prionocera dimidiata Lw. (Fig. 27). Hitherto the larvae of the Tipulini, in which tribe these species belongs, have not been considered carnivorous.

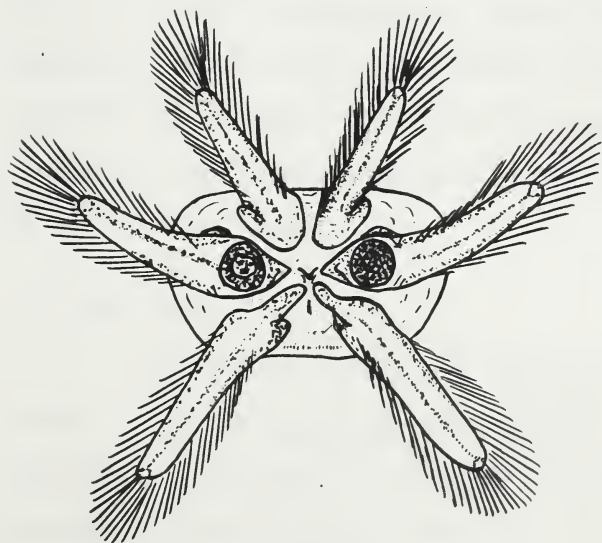
Larvae of P. dimidiata were sent to Dr. J. S. Rogers (25) University of Michigan, for descriptive purposes since no description exists of the immature stages of any species of Prionocera.

It is significant to note that in the field, Chrysops larvae were seldom found in any numbers where tipulid larvae

Prionocera dimidiata



Larva x 4



Caudal Segment x 20

FIG. 27

were plentiful. The predatory habit of the larvae of P. dimidiata, along with its abundance could account for the relative paucity of Chrysops as compared to Hybomitra at Churchill.

iv. Fungal Growth- On a few occasions it was noted in the insectary rearings that larvae and pupae supported an apparent fungal growth. In every instance the specimen subsequently died. This cause of mortality was obviated by soaking the moss in a 1 percent solution of 'Moldex', a proprietary fungicide. This treatment had no noticeable effects on larvae or pupae.

Throughout the season, 37 out of 123 Chrysops spp., and 11 out of 127 Hybomitra spp. larvae, died whilst in rearing. This represents a mortality of 30 and 6 percent respectively. The high mortality of Chrysops spp. was due primarily to the losses suffered by predation at the beginning of the season.

3. LARVAL FOOD

As previously indicated, tipulid larvae served ideally as food for Hybomitra spp.. Tipulid larvae were encountered in the field in the ratio of approximately 3 tipulids to 1 tabanid larva. These were all retained and fed to the Hybomitra spp. at the rate of one per day. Later in the season, when tipulid larvae were becoming increasingly

difficult to obtain, a substitute had to be found. Sluggish streams and stagnant pools abounded in snails, Limnaca and Physa spp., and these proved to be most acceptable. It was possible to collect 200-300 snails in 2 hours using an ordinary kitchen sieve and sweeping through the water. The snails were kept in an improvised aquarium and fed to the tabanid larvae as required. By twisting and turning their bodies, Hybomitra spp. larvae are able to get well inside even a small shell, and completely empty it.

Hybomitra spp. were observed feeding on annelids and slugs but these were so difficult to find that no serious attempt was made to obtain them for routine feeding purposes.

On rare occasions, Hybomitra larvae were observed taking a meal of raw beef and liver which was proffered, but generally speaking, the larvae require living material. The few larvae which would partake of a raw meat meal could be easily distinguished from those which did not by the deep red coloration of the gut contents showing through the integument. A further disadvantage in feeding larvae raw meat is that decomposition gives a foul odor to the container.

Chrysops larvae required very little attention. Cameron (5) found that these larvae require a soil medium rich in decaying organic material for successful growth. The same statement can be made for the northern species, substituting

'moss' for 'soil'. Very few deaths occurred if the moss was periodically changed, and at the end of observations for the season, all larvae appeared to be healthy.

The amount of food given each larva varied considerably. During the month of June, one tipulid larva or one snail was given to each Hybomitra larva per day but as the season progressed into July and August, when these sources of food became relatively scarce, this ration was reduced. It later appeared that this ration was far in excess of their normal requirements; larvae thus fed, became fat and sluggish and moulting apparently was retarded. The ration was reduced to 2 snails per week per larva beginning the first week in July and this proved to be ample. By the beginning of August, 1 snail per larva per week met the food requirements and this was continued without any visible ill-effects until the season ended.

Tabanid larvae generally are very hardy and not difficult to rear. An incident which bears out this remark is worth mentioning. A field-collected Hybomitra sp. larva, probably H. septentrionalis, which had been placed in a small shell-vial with a moist quantity of moss, was inadvertently left in the living quarters at Fort Churchill. The larva did not receive any food or water. Seven weeks later this larva was still alive and apparently suffering no ill-effects from its long fast. This larva was also subjected to temperature ranging between 43 and 85°F.

4. PARASITES

Parasitism of tabanid pupae was suspected early in the season when empty pupal skins of both Hybomitra spp. and Chrysops spp. were found with numerous small holes throughout their lengths. Dissections of pupae suspected of being parasitized (parasitized pupae become darker much faster than non-parasitized pupae) produced numerous larvae of the Chalcidoidea. These larvae were too small for further identification. The entire thoracic and body cavities of the pupae were filled to capacity. Later in the season, 90 small chalcids emerged from a single Hybomitra sp. pupa which was in rearing at the insectary. These were identified by Dr. O. Peck, Systematic Unit, Division of Entomology, as Diglochis occidentalis Ashm. (Pteromalidae). Hitherto, this species has not been recorded as a parasite of Hybomitra spp. pupae, although Cameron (5) reared it from C. moerens, mitis, and excitans.

Up until the time that the parasites began emerging from insectary-reared material it had been assumed that the parasitism occurred only in the pupa. However this assumption had to be discarded since the chalcids emerged from pupae, the larvae of which had been collected in early June, when the adult insect fauna in northern latitudes is practically nil. Furthermore, the larvae and pupae were kept in sealed jars, making entrance of a female chalcid impossible.

The assumption is made that the parasite lays her eggs in a larva during the latter part of the summer. The winter is passed in the host larva either in the egg or very young larval stage. Apparently this parasitism does not affect the growing tabanid larva, or if it does, no evidence was found in the field to support this. A few dead larvae were found in the field but upon dissection it was shown that death resulted from causes other than parasitism. Once the larva had pupated it was just a matter of a few days before the parasites had devoured the contents of the pupa.

In the insectary, pupae were left in the same moss in which the larvae were reared. Many of the adults emerging were in poor condition owing to the fact that the moss was too moist, and the adult was not afforded an opportunity to become dry. This condition was suitably altered by transferring newly formed pupae to dry, or slightly moist moss. Thereafter, all adults emerged in good condition.

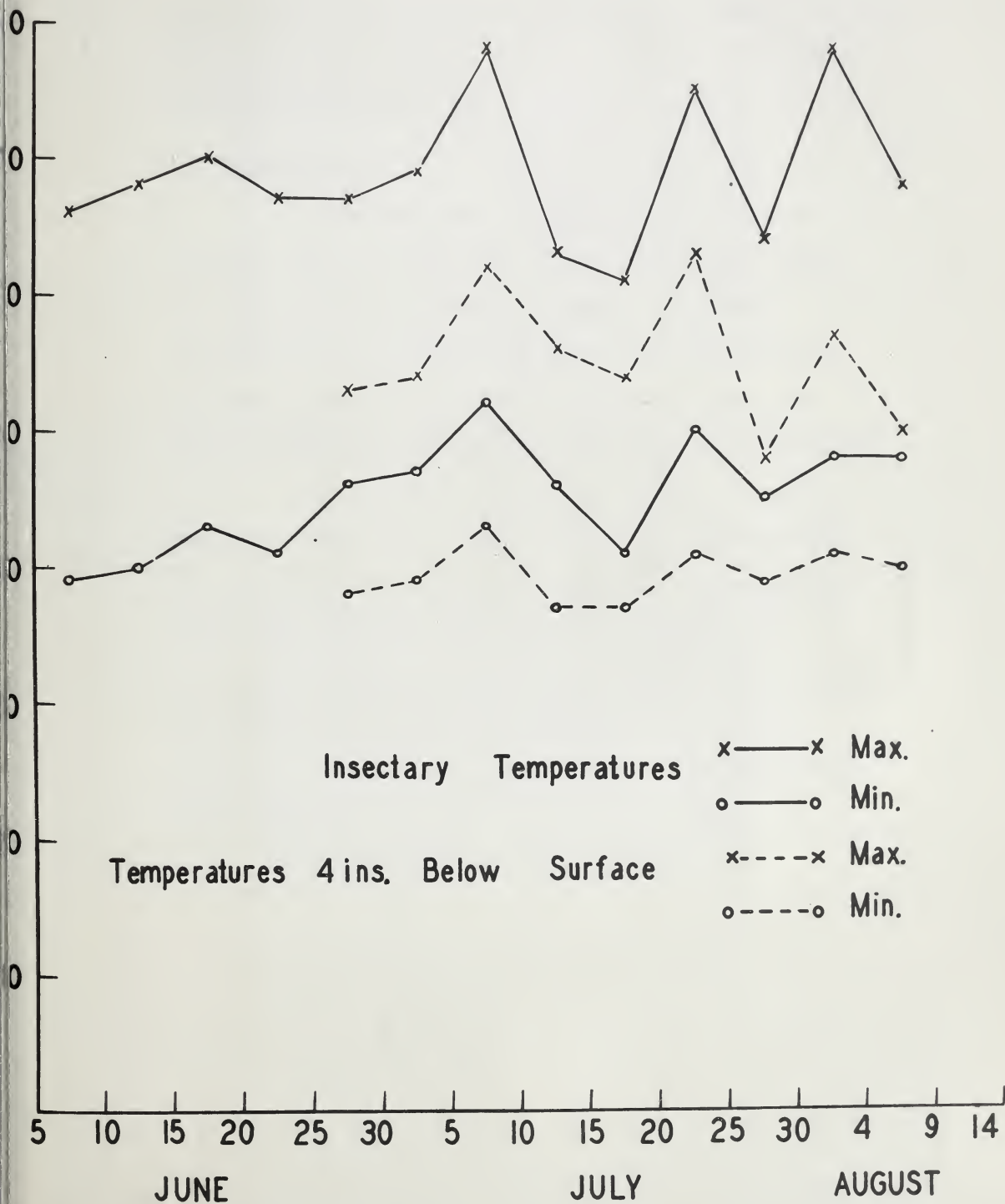
5. EFFECT OF ENVIRONMENTAL CONDITIONS ON DEVELOPMENT

Although it is desirable to simulate as nearly as possible the natural environment of the immature stages, it is obviously impossible to duplicate this exactly. Constant handling, confinement, different food supply, and temperatures are some of the more important factors which must apply in the insectary.

Daily maximum and minimum temperatures were recorded inside the insectary and 4 inches below the surface of moss in the field. Five-day averages were computed and the results are shown in Fig. 28. The average mean daily temperature in the insectary was 9.5°F higher than the average mean daily temperature 4 inches below the moss.

Of the 4 important factors considered, larvae are affected by all. Larval development of Chrysops spp. in the insectary apparently is not retarded by the difference in conditions for pupae were first found in the field on June 27th and pupation in the insectary occurred on the same day. A Hybomitra spp. pupa, on the other hand, was first found in the field on June 21st and in the insectary pupation did not occur until June 30th.

However, of the factors considered, pupae are affected by only temperature, and handling to a lesser degree. C. nigripes was obtained in the insectary in more than double the combined numbers of the other species of Chrysops, so that it is probable that the pupa found on June 27th was of this species. If this were so, it would indicate a pupal stage lasting 33 days, in the field, for the first adult of this species was not seen until July 29th. The mean duration of the pupal stage for C. nigripes in the insectary was 17 days. Similarly, the Hybomitra sp. pupa found in the field on June 21st was probably H. septentrionalis and the adult of this species was



first observed on July 23rd. This indicates a pupal stage lasting 33 days in the field as compared to 23 days in insectary rearings.

6. OVERWINTERING

Of the 300 larvae originally in the insectary, by August 18th, 199 were still in the larval stage. Since the last pupation was recorded on August 2nd, these remaining larvae were caged and buried in a suitable area. The cage measured 6' by 3' by 1' and was constructed of 2" by 2" lumber and covered with a #28 mesh plastic screening.

When completed, the cage was placed in a hole in the tundra (Fig. 29), and then filled with vegetation which had previously been picked over for larvae. Hybomitra spp. larvae were segregated from those of Chrysops sp. by a partition to avoid predation. In 1950 these larvae, if they survive the winter under such conditions, will provide sufficient numbers to carry on the study of life cycles and larval habitats.



Fig. 29. Partitioned Cage in which Tabanid
Larvae were Placed for Overwintering

Chemical Control

The nature of the breeding places renders it extremely difficult to control the immature stages by chemical means. The larvae, being mainly subterranean, are insulated from the immediate effects of aerial spraying -- the only practical means of large scale insecticide application in the north. An insecticide, falling on saturated moss would tend to remain on the surface; penetration being prevented to a large extent by the lack of water circulation in the moss. The success of any material used as a tabanid larvicide will depend on its ability to reach the larvae below the ground surface or to bring the larvae to the surface where they will come in contact with the toxic principles. Three materials reputed to have the latter property were tested. The results are recorded below.

1. MATERIAL TESTED TO BRING LARVAE TO THE SURFACE

1.1. Bailey's Formula (2) consisting of 65 percent deodorized kerosene, 0.035 percent pyrethrins, 0.1 percent thiodiphenylamine, 0.5 percent Triton X-100 and 3/4 percent water. One square metre of apparent larval habitat was treated with 1 part of the mixture in 20 parts of pool water at 4 litres to the square metre. After 30 minutes no obvious emergence of larvae had taken place. A detailed examination however revealed one tipulid pupa, one small dipterous larva (not tabanid), and several blackfly adults -- all apparently affected by the solution. Blackflies apparently seek shelter in the moss,

A second square metre near the first was treated with twice the quantity at half the strength. Examination 30 minutes later revealed no surfaced organisms.

A third square, somewhat wetter than the previous two, was treated with 8 litres at 1 part in 80 parts of water. Examination after 30 minutes revealed no surfaced organisms. A pupa was found about 1 inch below the surface from which an H. affinis female emerged one week later.

1.2. One square yard of waterlogged larval habitat situated at the edge of a small pool was treated with a 0.3 percent solution of orthodichlorobenzene applied at 2 gallons per square yard. Examinations were carried out 5 minutes, 30 minutes, and 1 hour after application but no organisms had surfaced. Five tabanid larvae were found approximately 3 inches below the surface -- all apparently unaffected by the treatment.

A second square yard was treated using the same strength but applied at 4 gallons per square yard. Observations carried out as in the first application revealed 2 tipulid larvae only. Although very inactive when found, they soon seemed to lose all effects of the treatment. No tabanid larvae could be found in this area.

1.3. Worm Magnet - A commercial product which was tested in a similar manner as the above two and which also gave negative results.

2. CHEMICALS TESTED AGAINST LARVAE

2.1. 25 PERCENT DDT EMULSION CONCENTRATE

Larvae used in this test were collected May 16th in a swamp area 3 miles west of the Edmonton city limits. Many larvae were found on the edge of a small pool bordered by spruce and large trees, (Fig. 30, upper). Fifteen larvae were taken from a small hummock not more than 1 foot square, which projected 5 inches above the water level. The edge of a much larger pool (Fig. 30, lower) yielded 35 larvae in 2 hours. The larvae were found just above the water line in decaying organic debris; there was no moss here. Larvae were also found in decaying, prostrate bulrush stems, and under fallen wood, in one instance in an old buprestid tunnel. Some of these larvae were reared and all adults, except one, were identified as C. furcata. The exception was Atylotus bicolor Wied., a new record for this area.

Sixty larvae were used in the insecticide tests and the results are shown in Table 9. A 'dip method', less elaborate than that of McIntosh (38), was used in this test. Larvae were placed in 4 oz. specimen jars with cheesecloth coverings and then immersed in the solution. Water used to dilute the emulsion concentrate was obtained from the pools in the areas where larvae were found. This water had a pH of 6.5 and at the time of testing, the temperature was 64° F. During the time of immersion the solution was agitated continually. The



Fig. 30 Larval Habitat of C. furcata near the
Western Outskirts of Edmonton, Alberta.

Table 9. Toxicity of DDT emulsions and a parathion suspension to tabanid larvae.

DDT concentrate (p.p.m.)	Time (mins.)	Larvae		Mortality after treatment		Pupa- tions
		Hybomitra	Chrysops	1 hr.	24 hrs.	
Check	10		15	0	0	7
250	10		15	0	0	8
1,000	10		15	0	0	9
16,000	10		15	1	1	3
Parathion						
Check	10	7	2	0	0	
250	10	7	3	0	0	

check batch was immersed in plain slough water. All batches remained equally active for the first 5 minutes but from then on activity gradually decreased, particularly in the higher concentrations, until at the end of the experiment only 2 larvae were moving in the solution containing 16000 ppm. On examination it was found that in some the oral hooks were in constant, but slow motion, while in others the gut could be seen contracting and expanding.

All larvae were rinsed in slough water at the completion of the experiment and individually segregated in test-tubes containing moist moss.

2. 2. On August 7th, a 25 percent parathion wettable powder, (Thiophos 3422), was tested against 19 larvae at 250 ppm parathion. These larvae were brought to Edmonton from Churchill. During immersion larvae in the check and treated batch were equally active. Results are given in Table 9.

3. DDT AGAINST PUPAE

Throughout the season at Churchill, larvae which were not used in the actual rearing experiment were reared through to the pupal stage for insecticide tests. The same dip method was employed. Before being immersed all pupae were apparently lifeless but as soon as their bodies came in contact with the liquid they suddenly became active and remained so throughout the experiment. Results of this test

are shown in Table 10, and although the number of pupae involved in the test is very small, it would appear that DDT might hold some promise as a pupicide.

Discussion

It is the opinion of the author that chemical control of the immature stages of tabanids is not economically feasible with existing insecticides and methods of application. Also, there is such an overlapping of larval instars and pupae in the field that a chemical which was only effective against a particular stage would fail entirely. Even if a suitable insecticide were found, the problem would still be far from solution.

Whilst no actual experiments against adults were carried out, the observer was able to watch the knock-down of females of H. affinis and H. septentrionalis within 5 minutes of coming in contact with a window sprayed with a 5 percent DDT-pyrethrin proprietary spray.

TABLE 10 - Toxicity of a DDT emulsion to pupae
of Hybomitra and Chrysops

DDT conc. (ppm)	Time (mins.)	Numbers		Parasitized		Emerged	
		<u>Hybo.</u>	<u>Chry.</u>	<u>Hybo.</u>	<u>Chry.</u>	<u>Hybo.</u>	<u>Chry.</u>
Check	10	4	13	0	3	1	7
1000	10	5	13	0	6	0	0

DISCUSSION

The females of H. affinis, metabola, zonalis and C. furcata were not reared in the insectary despite the fact that their combined numbers exceed the combined numbers of the remaining tabanid species. No explanation ^{of} ~~to~~ this anomaly is apparent, but the following possibilities are suggested:

(1) The larvae of these species were not found.

However one feels justified in discarding this since, on a basis of mathematical chance, a few of the 80 emergences would be expected to be of the 4 species. Also 1 male of H. affinis and 1 of C. furcatus were reared which would indicate that searching was conducted in an area where these immature stages did occur, although perhaps in sparse numbers.

(2) Selective mortality of the 4 species in the insectary (See Chapter IV).

(3) Only early instars of these species were found.

This would of course suggest that the late instars occupy a very restricted habitat which was missed in our searching. If the emergences in 1951 from the overwintering larvae are predominantly these species, this explanation will be the most satisfactory and will suggest a search for late instars in situations hitherto deemed unsuitable.

The problem of controlling tabanids in treeless terrain is non-existent, for these pests are always found associated with woodland. However, the northland south of the tree line offers vast ideal breeding areas, for the entire countryside is dotted with small lakes and pools, the margins of which, in particular, abound in immature stages (See pp.39,41). In this connection it should be possible, from aerial photographs, to make a reasonable forecast as to the nuisance to be expected from tabanids in any particular area. For a given proportion of water to land, the total length of shore line per unit area, and consequently the potential tabanid breeding area, is inversely proportional to the area mean diameter of the pools.

Gerry (36) has reported the control of adults of Tabanus nigrovittatus throughout the season over a 15-mile section of shoreline by 2 applications of DDT-oil spray, containing 1 percent by weight of aluminum stearate, at 1 pound of DDT per acre. The problem here was simplified in that all stages were concentrated along a single shoreline and consequently the spraying required only two swaths from an aircraft to give effective coverage. To control tabanid adults in the north, aerial spraying would have to cover many square miles on account of rapid infiltration, and at the dosage which Gerry found necessary, this would be quite uneconomic. Furthermore, such an application should immediately precede emergence of the

important biting species. The spread of these emergences however is so great, namely from the first week in July to the first week in August, that even if application were possible, an effective deposit would not persist for this period. Data on control of adults could well be obtained as a secondary result from large scale aerial spraying against forest insects if such spraying was coincidental with peak adult population. The evidence available (Table 10) suggests that the pupal stage is the most susceptible to DDT. Furthermore, at this stage they are either at the ground surface or slightly below, and have a far greater chance of coming in contact with the insecticide, than do the subterranean larvae. However, until a material is found that is more specific and cheaper than present day insecticides, the chemical control of tabanids from large scale spraying is extremely unlikely to prove economic.

Although chemical control by aerial application is not practical, two other methods of using chemicals warrant consideration.

(1) Enclosures could be built in various adult habitats at small cost from any waste material and the inside sprayed with a DDT-pyrethrin formulation. Such an enclosure would be partially open at one end and contain at least one light-admitting opening around which the flies would congregate (37).

(2) Large frames covered with tar-paper and spread

with a non-drying adhesive should also prove effective. Insect populations have been studied by Brues (35) using this adhesive method. It is believed that these 2 methods would prove effective in affording a measure of relief in localized areas while at the same time, they could provide extremely valuable data on relative abundance, succession of species, adult populations and habits.

Were it not for the presence of the very abundant predatory tipulid larva, P. dimidiata, the biting fly picture in the north might well be one in which the deerfly problem would be of primary importance. These larvae devour untold numbers of Chrysops larvae. Similarly, the small chalcid, D. occidentalis, perhaps plays an important part in keeping species of both important genera in check. These parasites, judging from the numbers which can emerge from one pupa, must be present in tremendous numbers, although they are seldom seen. The eggs of the Tabanidae when found, will probably have their complement of parasites. That the tabanid problem is not as serious as one might envisage is largely due to these two biological factors.

Suggestions for Further Investigations

1. An intensive rearing program with the emphasis placed on the species not obtained during 1949. This would include finding

- and rearing the larvae of H. metabola, H. zonalis,
· C. mitis and C. carbonaria. No females and only 1 male
of H. affinis, 1 of C. furcata were reared.
2. Cage field collections should be continued using larger
cages constructed of more durable material (See p. 89).
 3. Weather conditions were very adverse during the period of
observation. Further investigations should be carried out
correlating adult activity with weather conditions.
 4. Further efforts to locate eggs in the field will have to be
made. When these are found, more definite information can
be obtained on the species by rearing adults. If successful,
ovicidal investigations could be carried out. Also attempts
should be made to 'induce' oviposition in captivity and it
may also be possible to rear larvae from dissected eggs.
 5. Further tests of insecticides against the immature stages
and adults are required.
 6. If possible, aerial photographs should be studied prior to any
season's investigations in a new area to ascertain the
feasibility of establishing population estimates by this method.

REFERENCES

1. ALEXANDER, C. P. - Unpublished communication addressed to E. H. Strickland. - November 4, 1949.
2. BAILEY, N. S. - A mass collection and population survey technique for larvae of Tabanidae (Diptera). Bull. Brook. Ent. Soc. 43: 22, 1948.
3. BAILEY, N. S. - Notes on Tabanus atratus subsp. nantuckensis Hine, (Diptera). - Bio. Abst. 23: Item 13501, 1949.
4. BRENNAN, J. M. - The Pangoniinae of Nearctic America Tabanidae: Diptera. - Bull. Univ. Kansas 36: 249, 1935.
5. CAMERON, A. E. - Bionomics of the Tabanidae of the Canadian prairie. Bull. Ent. Res. 17: 1, 1926.
6. CORDROY, M. R. L. Bourgault du - Trap for the destruction of cattle flies. - J. Royal Army Med. Corps. 54: 208, 1930.
7. FRAENKEL, G. S. and GUNN, D. L. - The orientation of animals. Oxford University Press, 1940.
8. GJULLIN, C. - Notes on the biology and control of Chrysops discalis (Williston). Proc. Ent. Soc. Wash. 47:236, 1945.
9. HAGMAN, L. E. et al - Evening flight habits of a male tabanid. Ent. News. 59: 257, 1948.
10. HATTON, G. N. - Notes on the life history of some tabanid larvae. Proc. Ent. Soc. of B.C. 44: 15, 1948.
11. HINE, J. S. - Horseflies collected by Dr. J. M. Aldrich in Alaska in 1921. Can. Ent. 55: 143, 1923.

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12. HOCKING, B. - Some aspects of the biting fly problem in Canadian sub arctic regions. 1948 Unpublished.
13. HOWELL, D. E. et al - Effect on horse fly populations of aerial spray applications to wooded areas.
J. Econ. Ent. 42: 644, 1949.
14. JONES, T. H. and BRADLEY, W. G. - Observations of Tabanidae in Louisiana. J. Econ. Ent. 16: 307, 1923.
15. LOGOTHEtis, C. and SCHWARDT, H. H. - Biological studies on the horseflies of New York. J. Econ. Ent. 41: 335, 1948.
16. MARCHAND, W. - An improved method of rearing tabanid larvae.
J. Econ. Ent. 10: 469, 1917.
17. MARCHAND, W. - The early stages of Tabanidae (horse flies).
Mon. Rock. Inst. Med. Res. No. 13, 1913.
18. PECHUMAN, L. L. - Some notes on Tabanidae (Diptera) and the description of two new Chrysops. Can. Ent. 81:77, 1949.
19. PHILIP, C. B. - The Tabanidae - Horseflies of Minnesota with special reference to their biologies and taxonomy.
Minn. Agr. Exp. Sta. Tech. Bull. 80: 10, 1931.
20. PHILIP, C. B. - The furcatus group of western North American flies of the genus Chrysops (Diptera: Tabanidae).
Proc. Ent. Soc. Wash. 37: 153.
21. PHILIP, C. B. - Comments on the supra - specific categories of nearctic Tabanidae (Diptera). Can. Ent. 73: 2, 1941 .
22. PHILIP, C. B. - Method of collecting and rearing immature stages of Tabanidae. J. Parasit. 14: 243, 1928.

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10. The tenth part of the book is devoted to the study of the properties of the function of the variable x .

11. The eleventh part of the book is devoted to the study of the properties of the function of the variable x .

23. PHILIP, C. B. - New North American Tabanidae (Diptera).
Part I - Pangoniinae. Ann. Ent. Soc. Amer. 42: 451, 1949.
24. PORTCHINSKY, L. - Tabanidae and the simplest methods of
destroying them. Abstr. in Rev. Appl. Ent. (B) 3:195, 1915.
25. ROGERS, J. S. - Unpublished communication. - Nov. 29, 1949.
26. ROTH, A. R. and LINDQUIST, A. W. - Ecological Notes on the
deerfly at Summer Lake, Oregon. J. Econ. Ent. 41:473, 1948.
27. SEGAL, B. - Why not Bourgault's trap for horse-flies?
J. Econ. Ent. 26: 301, 1933.
28. STONE, A. - The horseflies of the sub-family Tabaninae of
the nearctic region. U.S.D.A. Misc. Pub. 305, 1938.
29. STONE, A. - The bionomics of some Tabanidae (Diptera).
Ann. Ent. Soc. 23: 261, 1930.
30. TASHIRO, H. and SCHWARDT, H. H. - Horseflies of central
New York. J. Econ. Ent. 42: 269, 1949.
31. TRAVIS, B. V. - Studies of mosquito and other biting-insect
problems in Alaska. J. Econ. Ent. 42: 251, 1949.
32. TWINN, C. R., B. HOCKING, Wm. C. McDUFFIE, and H. F. CROSS
- A preliminary account of the biting flies at
Churchill, Manitoba. Can. J. Res. D, 26: 334, 1948.
33. UVAROV, B. P. - Insects and climate.
Trans. Ent. Soc. Lond. 79: 1, 1931.
34. WEBB, J. L. and WELLS, R. W. - Horseflies: Biologies and
relation to western agriculture. U.S.D.A. Bull. 1218, 1924.

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- 2. The second is the fact that the...
- 3. The third is the fact that the...
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- 8. The eighth is the fact that the...
- 9. The ninth is the fact that the...
- 10. The tenth is the fact that the...

Supplementary List of References

35. BRUES, C. T. - Changes in the insect fauna of a New England woodland following the application of DDT.
Harvard Forest Papers 1: No. 1, 1947.
36. GERRY, B. I. - Control of the salt marsh tabanid by means of a residual DDT-oil spray.
J. Econ. Ent. 42: 888, 1949.
37. HEARLE, E. - Insects and allied parasites injurious to livestock and poultry in Canada.
Can. Dept. Agri. Farmer's Bull. 53, 1948.
38. Mc INTOSH, A. H. - A dipping apparatus for estimating to the toxicity of insecticides in liquid media. Ann. App. Biol. 34: 233, 1947.

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